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Cadmium Exposures in Silver Soldering Operations

GRANT H. VANCE, B.S.

Bureau of Industrial Hygiene, Connecticut State Department of Health

MANY cases of cadmium poisoning have been reported in the literature. Some resulted from ingestion of food or beverages from cadmium-plated containers.[1] However, industrial poisoning usually is caused by inhalation of cadmium oxide fume or dust. Spolyar,[2] Barrett[3] and others have reported on cases of acute cadmium poisoning. Investigations of chronic industrial exposures were reported by Hardy and Skinner[4] and by Princi.[5] However, there has been very little mention of exposures from silver soldering operations.

Silver soldering is essentially a low temperature brazing process used for bonding metals and alloys such as silver, copper, brass, bronze and stainless steel which do not respond readily to usual welding procedures. Special solders are used, commonly composed of alloys of silver, copper, zinc and cadmium. The cadmium content in many of these alloys varies from 15–25% although one special low-melting (740°F) solder contains 95% and some commercial alloys contain no cadmium. The fusion is accomplished by heating the metal to the flow point of the solder (1175° to 1295°F) by means of a gas-air torch, an oxyacetylene torch, or an induction heat unit.

The Bureau of Industrial Hygiene of the Connecticut State Department of Health has conducted a number of studies on various silver soldering operations as part of its program of evaluation and control of occupational health hazards in industry. These studies were made in various plants throughout the state to determine the exposure of the workers to cadmium under a variety of operating conditions. The value of 0.1 milligram of cadmium per cubic meter of air (recommended by the American Conference of Governmental Industrial Hygienists—Threshold Limit Values for 1958) was used as the threshold limit in evaluating the extent of health hazard.

All samples were collected on filter paper (Whatman #41 or fiberglass filter sheets with no organic matter and 0.75 micron maximum porosity) using a funnel apparatus at a sampling rate of 1.0 cubic foot of air per minute, and were analyzed by the polarographic method.[6] Briefly, the procedure is as follows:

(1) Dissolve samples in 20 ml concentrated HCl and evaporate to dryness.
(2) Heat in muffle furnace at 450°C for 30 minutes to eliminate organic matter.
(3) Dissolve residue in one ml normal HCl.
(4) Add 0.5 ml hydroxylamine hydrochloride and 0.2 ml potassium thiocyanate to eliminate iron and copper waves.
(5) Record polarogram using KCl as supporting electrolyte.
(6) Record polarogram of cadmium standard for comparison. (In some cases of excessive interference by iron and copper waves, the samples and standards were analyzed in alkaline medium using NH_4OH:NH_4Cl as supporting electrolyte.)

The atmospheric concentrations found during the studies, together with conditions of the test are shown in Table I.

It is interesting to note that only one plant using the gas-air torch and one plant using the induction unit showed concentrations in excess of the threshold limit. The gas-air torch operation, where one value slightly in excess of the threshold limit was found, utilized a triple burner arrangement which apparently produced too much heat at the joint. The induction unit, where the excessive concentration was found, may have been improperly adjusted so that excessive heat was applied. On the other hand, concentrations found in most of the plants using an oxyacetylene torch were above the threshold limit.

The temperature of a gas-air torch is approximately 3500°F and of the oxyacetylene torch is 6000°F. Induction unit temperatures depend on the amperage available. The amperage should be adjusted to provide temperatures in the 1175° to 1295°F range.

No apparent correlation is found between the cadmium content of the solder as used during these studies and the atmospheric concentrations in the workroom air. The atmospheric concentrations appear to depend primarily on the temperature of the operation and the operator's technique.

The oxyacetylene torch readily vaporizes cadmium or cadmium oxide fume into the air. There is also a greater possibility of the formation of

TABLE I

Plant	Product or type of work	% Cadmium in solder	Concentrations of cadmium in mg/m³	
			Breathing zone	General atmosphere 5–15 ft from operator
	Heat Source—Gas-air Torch			
A	Mfg. plating racks	24	0.03, 0.05, 0.06	
B	Knife blades to handles	14	0.03, 0.06, 0.03 0.04, 0.03, 0.03	
C	Holloware manufacture	17	0.05	
D	Oil burner manufacture			
	Double burner torch	24	nil	
	Triple burner torch		0.12	
	Heat Source—Oxyacetylene Torch			
E	Gauge manufacture	18	0.1, 0.37	0.05
F	Sunglass frame assembly	15	0.28, 0.38, 0.32 0.22, 0.15, 0.29 0.21	
	Same after installation of glass shields between operators and point of operation	25	0.08, 0.01, 0.01 0.02	0.03, 0.04 0.08
G	Assembly percolator spouts to percolator	15	0.28	0.02, 0.06
H	Brass tube assembly	18	0.01, 0.08, 0.02	
I	Plumbing goods	18	1.3	
J	Metal seat frames	16	0.35, 0.56	
	Heat Source—Resistance Units or Ovens			
F	Sunglass frames	15	0.30, 0.19, 0.16	
	(after installation of glass shields)	25	0.02, 0.01, 0.03 0.02	0.05, 0.03
H	Brass tube assembly	18	0.02	
I	Plumbing goods	18	0.08	
K	Electric appliances	19	0.06, 0.01, 0.04	

cadmium oxide from combination of cadmium with excess oxygen in the flame. This is particularly true during silver soldering on small pieces. Heat conductance away from the point of operation helps control the excessive temperatures during silver soldering on large pieces. The gas-air torch and the resistance units are slower heating than the oxyacetylene torch so that control of working temperatures is less difficult.

The results of these studies show that it is advisable to provide mechanical exhaust ventilation on all silver soldering operations using oxyacetylene torches to control the cadmium fumes and to avoid any occupational health hazard. At times, it may be advisable to provide exhaust control for gas-air torch and resistance-type operations dependent on all conditions existing at each individual operation. Each operation should be appraised and evaluated by competent observers and control recommendations made if necessary to prevent injury to the health of the workers.

Movable exhausted hoods similar to those used for control of welding operations provide adequate control of intermittent and varying silver solder operations. Production line operations may be controlled by provision of exhausted booth-like enclosures (Figure 1) or hood (Figure 2). This is the preferred method although one plant (Table I—Plant F) was able to achieve control by diversion shields in a well ventilated area.

Summary

Silver soldering has been shown to be a potential source of exposure to excessive concentrations of cadmium or cadmium oxide fumes. The prob-

FIGURE 1. Exhausted, booth-like enclosure.

FIGURE 2. Exhausted hood.

ability of excessive concentrations increases with the use of high temperatures such as those found when oxyacetylene torches are used. Operating technique and the size of the pieces were also found to be factors in the production of excessive atmospheric concentrations of cadmium. In general, mechanical exhaust ventilation is recommended for all oxyacetylene silver soldering operations and may be advisable on some gas-air or resistance heating units depending on the evaluation of conditions found.

Grateful acknowledgement is given to the staff of the Bureau of Industrial Hygiene for the technical data developed.

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M.I.T. Course on Noise Reduction

THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY announces that it will again offer a special summer program on Noise Reduction from Monday, August 22 through Friday, September 2, 1960.

This two-week program will be under the direction of Dr. Leo L. Beranek, Department of Electrical Engineering, assisted by other M.I.T. faculty members and industrial engineers. The program will be taught on a case history and problem solving basis with a minimum of formal lectures. The foundation material will be derived from a new text *Noise Reduction* to be supplied to all enrollees.

The program is directed toward the engineer who has been assigned a noise problem for solution. The first week's topics include behavior of sound waves, decibles, selection and use of instrumentation, and sound in enclosures. The second week's subjects include structures and materials for absorption and attenuation of sound, mufflers, criteria for noise and vibration control, and case histories. Students must attend both weeks. In addition to the class instruction, there will be exhibits, a field trip, and entertainment features.

Treatment of Exhaust Gases from Boron Fuels

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General Electric Company, Evendale, Ohio

Introduction

EXHAUST gases produced from the burning of boron fuels such as trimethyl borate contain solid boron oxide existing as extremely small particles suspended in the exhaust gas stream. These particles form a dense white smoke when the untreated exhaust is discharged directly to the atmosphere. Photomicrographs show the boron oxide particles range in size from two microns down to less than 0.3 micron. Several systems for treating these exhaust gases were evaluated, in an effort to determine an efficient and economical process for removing the boron oxide.

Wet Scrubbing System

The wet scrubbing process was first investigated. In this process the boron oxide particles are removed from the exhaust gases by water droplets. The boron oxide thus separated exists as a solution of boric acid, H_3BO_3. A conventional spray-type scrubber was used, employing eight banks of water sprays plus an entrainment separation and wash section. The internal arrangement of the water sprays, entrainment separator and wash nozzles is shown in Figure 1. The scrubber has an overall height of 48 feet and is designed to handle exhaust gas flows up to about 16 lbs/sec. Exhaust gases enter the scrubber and rise through the counter-current flow of water droplets from the spray nozzles. The solid particles are removed by impingement upon the liquid droplets, or deposited on the liquid drops by Brownian diffusion or motion. This latter mechanism will predominate for the sub-micron particles. The small water droplets carried upward by the gas stream are removed in the entrainment separator, which is kept clean by coarse water sprays at the top of the scrubber. To evaluate scrubber performance, samples of the scrubber outlet water were analyzed for boric acid. Total water flow into the scrubber was measured, and the water evaporated by the hot gases was calculated and subtracted from the total water input. Scrubber efficiency was then calculated by the following formula:

$$\text{scrubber efficiency} = \frac{\text{boric acid in outlet water}}{\text{calculated boric acid entering system}} \times 100$$

This provided the simplest and easiest method of efficiency measurement, since the inlet boric acid could be computed from the experimental burner fuel flow. Also, the outlet water flow and acid concentration could be measured with good accuracy.

Sampling

This method, however, did not measure the solids discharging from the exhaust stack, which were also a function of burner performance and deposition of solids within the system as well as scrubber efficiency. Therefore, a system for measuring the concentration of boric acid in the scrubber exhaust gases was devised. Figure 2 shows an assembly of the equipment that made up this sampling system. A measured sample of exhaust gas is drawn through a weighed laboratory Soxhlet thimble used as a filter. After passing through the filter, the exhaust gas is drawn through a wet gas meter where the gas volume, temperature and pressure are measured. Concentration of the solids in the gas stream may be calculated from the sample weight and gas volume. Efficiency of the scrubber or collector can be calculated as follows:

$$\text{removal efficiency} = \frac{\text{Conc. } H_3BO_3 \text{ inlet} - \text{Conc. } H_3BO_3 \text{ outlet}}{\text{Conc. } H_3BO_3 \text{ inlet}} \times 100$$

This method has the advantage of measuring directly the solids entering and leaving the collector. It requires careful weighing of the filter thimble both before and after the sample is taken. Also, this thimble weight must be corrected for the amount of water absorbed by the thimble during the test. A second weighed thimble is included in the sampling flask downstream of the sampling thimble. The change in weight of this second thimble represents moisture taken up or lost, and this correction factor is applied to the filter thimble.

Wet Scrubbing Efficiency

Scrubber performance was measured at various conditions of solids concentration and gas flow. To determine the effect of solids concentration, the fuel-air ratio at the burner was varied while

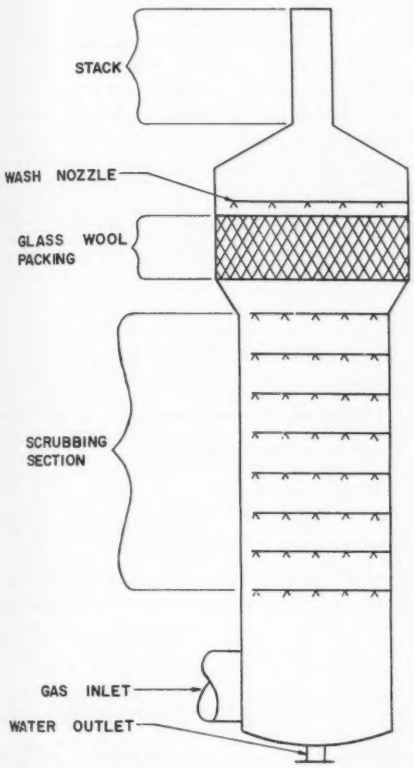

FIGURE 1. Schematic diagram, spray-type scrubber.

inlet air flow was held constant. The effect of solids concentration was measured at air flow rates of 5, 8, and 12 pounds per second. The results were typical for this type of scrubber, showing decreased efficiency as the solids concentration increased (Figure 3), and rapidly decreasing efficiency as the exhaust gas flow increased (Figure 4).

Cloth Filtration

A commercial-type filter equipped with fiberglas filter cloth was evaluated next. This unit, supplied by the Wheelabrator Corporation, permitted filtration of high temperature gases up to 500°F. The solid particles are removed by passing the exhaust gases at low velocity through glass cloth. Filter velocities depend on dust concentration, particle size and filtration time cycle. Preliminary tests were run with square foot samples of the glass cloth to evaluate its filtration characteristics. The boron oxide fumes were produced by a small laboratory burner, and gas-to-cloth ratios were varied from 1.21 to 1 up to 3.84 to 1. By measuring pressure drop across the cloth at regular time intervals, the filtration characteristics of the boron oxide were determined and the specific resistance of the filter calculated by the following equation:

$$K = \frac{Rf - Ri}{LTV^2}$$

where K is the specific resistance of the filtered dust—

Rf is the final filter resistance.
Ri is the initial filter resistance.
L is the dust loading of the inlet gas.
T is the time to reach Rf.
V is the filtration velocity, or air to cloth ratio.

The best overall filtration characteristics were obtained at 3 to 1 air-cloth ratio, and a K factor of 415 was calculated.

Filtration efficiencies as high as 99.0 percent were obtained with the experimental filter, and typical performance data are shown in Table I. Since precooling of the exhaust gases was required prior to filtration, it was important that

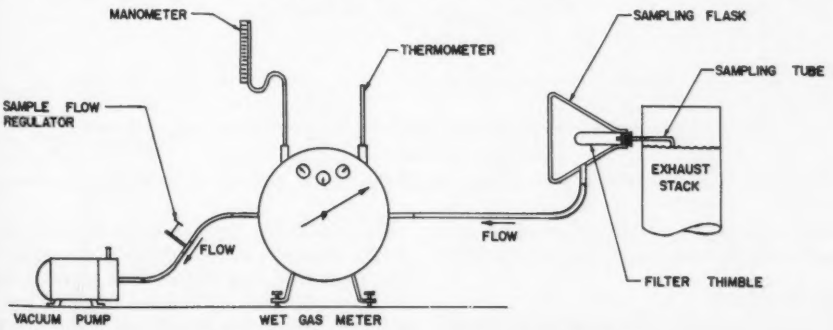

FIGURE 2. Exhaust gas sampling equipment.

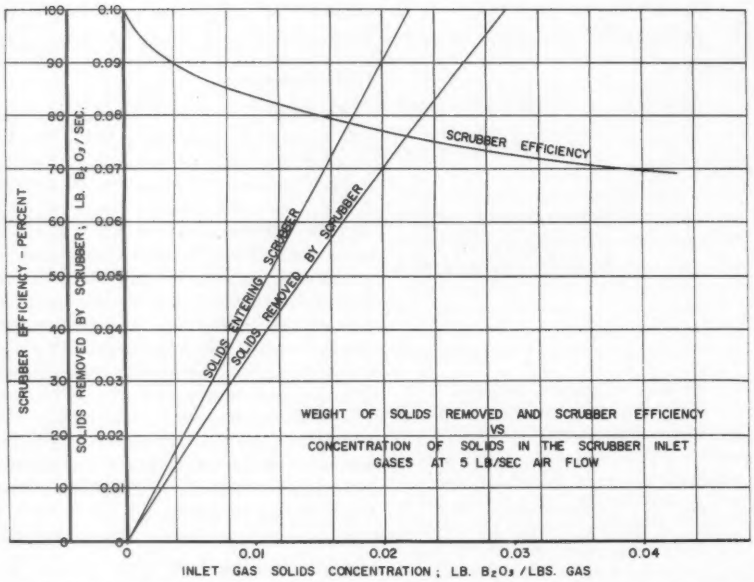
SCRUBBER EFFICIENCY - PERCENT
SOLIDS REMOVED BY SCRUBBER; LB. B2O3/SEC.
SCRUBBER EFFICIENCY
SOLIDS ENTERING SCRUBBER
SOLIDS REMOVED BY SCRUBBER
WEIGHT OF SOLIDS REMOVED AND SCRUBBER EFFICIENCY
VS
CONCENTRATION OF SOLIDS IN THE SCRUBBER INLET
GASES AT 5 LB/SEC AIR FLOW
INLET GAS SOLIDS CONCENTRATION; LB. B2O3/LBS. GAS

FIGURE 3. Weight of solids removed and scrubber efficiency vs concentration of solids in the scrubber inlet.

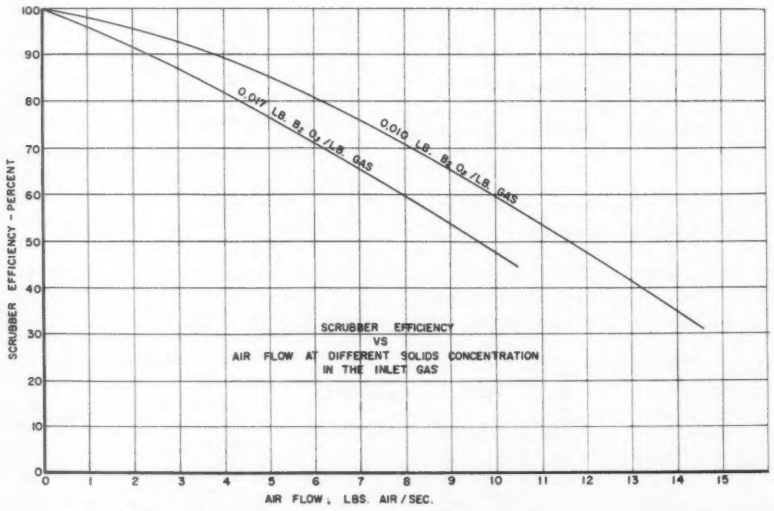

FIGURE 4. Scrubber efficiency vs air flow at different solids concentration in the inlet gas.

the water droplets were completely evaporated, or separated from the gases before entering the filter.

Quench Scrubbing

During the scrubber evaluation tests, the effect of increased quench water on scrubber efficiency was noted. Quench water was being added to the exhaust gases immediately downstream of the burner, cooling the exhaust gases to 700°F or lower. Control of the quench water flow was variable during the initial tests, and the data indicated a correlation between quench water

flow and scrubber efficiency. As a result of this observation, quench water flow was increased to about twice normal and the scrubber efficiency measured. At this high quench flow the scrubber efficiency increased to 99.5% (Table II).

For an independent evaluation of this method for removing boron oxide from the exhaust gases, an experimental quench water injection and cyclone separator system was constructed (Figure 5). This system permitted injection of coarse water droplets into the exhaust gases at their hottest point, and over a wide flow range. The entrained water droplets containing the boron oxide were then separated from the gas stream in a cyclone separator. During later experiments, a conventional water scrubber was substituted for the cyclone separator. A comparison of the efficiency of the system for removing boron oxide is shown in Figure 6. It is interesting to note that the removal efficiency increases as injection water flow is increased, up to about three times the amount of water required to saturate the gases with water vapor. Beyond this point the removal efficiency decreases. Also, the combination of quench water injection plus conventional scrubbing gives better efficiency than the injection plus mechanical separation. This is probably due to

TABLE I

Filtration of Boron Oxide from Exhaust Gas

Filter cloth area	252 ft²
Gas volume to collector	627 cfm
Filter inlet temperature	440°F
Filter inlet pressure	Atmospheric
Dust Loading	
Inlet gases	2.660 Grains/ft³ (STP)
Exit gases	0.026 Grains/ft³ (STP)
Filter resistance after 9 minutes operation	5.0 in. H_2O
Inlet gas moisture	0.339 lbs./lb. dry gas
Inlet gas dewpoint	163°F
Filter efficiency	99.0 per cent

TABLE II

Scrubber Efficiency vs Quench Water Flow

Air flow lbs./sec	Solids concentration lb./lb. gas	Quench water lbs./sec	Scrubber efficiency per cent
8.0	0.0170	7.08	99.5
8.0	0.0176	3.96	74.2

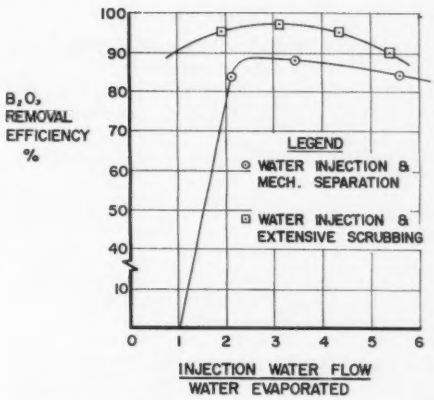

FIGURE 6. Effect of water injection for removal of B_2O_3 .

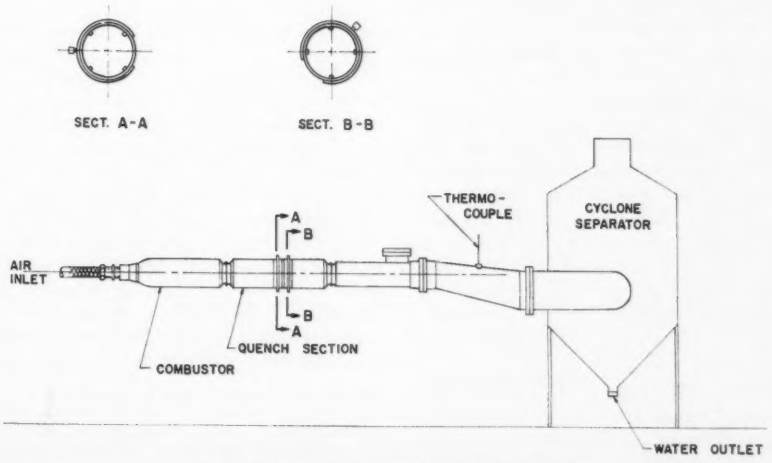

FIGURE 5. Quench scrubber and separator.

TABLE III
Variation in Scrubbing Efficiency with Gas Temperature

Air flow	Quench scrubber inlet gas temp.	Scrubber efficiency
8.0 PPS	502°F	73.3 per cent
8.0	>2000	99.5

TABLE IV
Comparison of Solids Removal Efficiency Boron Oxide vs Ferric Oxide Dust

Solid	Exhaust gas flow lbs./sec	Inlet gas temp.	Injection water ratio	Inlet solids concentration gms/ft³	Efficiency solids removal per cent
Boron oxide	0.40	2000°F	5.6	0.570	84.5
	0.50	2000	3.4	0.443	88.1
	0.75	2000	2.1	0.450	83.8
Ferric oxide	0.40	2000	14.0	0.149	21.4
	0.50	2000	5.0	0.092	14.0
	0.75	2000	5.3	0.063	0.0

the decrease in carryover of the boron oxide-laden water droplets by the scrubber.

The introduction of a large number of coarse water droplets into the exhaust gas at its hottest point is a significant factor, since the same quantity of water added to the gases after they have been cooled is not nearly as effective (see Table III). This may be explained by considering the water droplets as nuclei of condensation for the boron oxide which exists as a vapor in the hot exhaust gas. The boron oxide vapor condenses on the droplets which are large enough to resist complete evaporation in the hot gas stream. Once condensed onto the water droplets, the boron oxide remains in the droplets and cannot re-enter the gas stream. If, however, the gases are first cooled and boron oxide exists as minute solid or liquid particles, then these particles are removed only by the random contact of conventional scrubbing.

To verify this theory, experiments were carried out using finely divided ferric oxide dust (1 to 20 microns) injected into the experimental scrubber in place of the boron oxide. Burner temperature was maintained by burning conventional hydrocarbon fuel, and all test conditions were held as closely as possible to those used in the boron fuel tests. A comparison of the results (Table IV) shows almost insignificant removal of the ferric oxide dust by the injection scrubbing system. Thus, when the boron oxide exists as solid particles in the gas stream, the quench water injection system is ineffective for removing these particles.

Summary and Conclusions

The results of this investigation show that boron oxide particles in the exhaust gases from boron fuels can be removed by industrial-type scrubbers or filters operated within defined limits. However, the introduction of coarse water droplets into the high temperature exhaust gases, with subsequent separating of the droplets from the gas stream, effectively removes the boron oxide before the smoke particles are formed. This provides a simple, economical and effective system of exhaust gas treatment which is specific for boron oxide.

Constant Flow Regulators for the High-Volume Air Sampler*

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THE high-volume air sampler, using the 8- x 10-inch glass fiber filter for collecting atmospheric particulate has found very wide acceptance.[1, 2] The ability of this device to collect large samples is one of the main requirements of a variety of analyses performed in the study of air pollution, namely, chemical, radiological, and toxicological. However, the accuracy with which such a device gives a representative sample of the particulate content of the atmosphere or a measure of the average dust concentration is often overlooked. In the sampler as usually used, the fan has a characteristic curve which shows a progressive decrease in flowrate as a result of sample build-up on the filter (Figure 1, Curve A–B). The collected particulate is effective in reducing the air flowrate only to the extent that it increases the resistance of the filter to air flow. Particulate which tends to agglomerate, such as soot and tarry substances, will pack on the filter and significantly reduce the flowrate. Equal loadings of sandy and gritty dusts, by contrast, are not nearly as effective in reducing the sampling rate. Long term sampling (24 hours or more) of troublesome dusts will reduce the flowrate as much as 50% or more with loadings of approximately 300 mg. By comparison, the reduction by less troublesome dusts can be as low as 5% with loadings in excess of 300 mg.

It has been customary to compute air flow by multiplying the average of initial and final flowrate in cubic feet per minute (cfm) by the number of minutes of sampling. This computation is correct only if there is a linear decrease in flowrate for the duration of sampling. In theory, (Appendix A) flowrate decreases exponentially for constant dust concentration in the atmosphere. However, as will be shown later, experimental evidence indicates that the exponentials which usually occur (cf. $K = 0.029$ hr.$^{-1}$ in Fig. 5) closely approximate a straight line, so that the error in assuming a linear decrease is not great.

However, whether one accurately measures total flow by a large gas meter, computes it from the correct exponential, or closely approximates it by the assumption of a linear decrease, there can be appreciable error in the computed mean concentration of particulate per unit volume of air if the actual dust concentration varies significantly in any period of sampling during which sampling flowrate was continually decreasing. Thus, if concentration were higher during the first half of sampling than during the second half, the computed mean concentration would be greater than the true concentration and vice versa (Appendix B). Therefore, a regulating device to maintain air flowrate constant and independent of atmospheric dust concentration or filter loading would improve both the representativeness and accuracy of measurements. Although regulation for constant sampling has been achieved in a number of devices,[3, 4, 5] a constant flow regulator adaptable to the high-volume air sampler of the National Air Sampling Network type was not available.

Two prototype regulators were constructed; one operates on the principle of a bypass orifice acting as a varying parallel restriction, and the other uses a tapered annulus serving as a varying series restriction. Both function on the principle that if an initial total effective resistance is provided to give a flowrate reduced from that of the unregulated sampler, then this flowrate may be maintained as long as the effective resistance is held constant. The total effective resistance is the combination of the filter resistance and resistance of the regulator, and it is held constant by designing the bypass or series regulator resistance to vary directly or inversely, respectively, as the filter resistance. The range of pressure drops over which the regulator maintains constant flowrate is determined by the resistance initially provided by the regulator.

Bypass Regulator

The bypass regulator (Figure 2) consists of an orifice plate and tube assembly mounted in the center of a housing and acted upon by a preloaded coil spring. Holes in the orifice tube maintain the

* Presented at American Industrial Hygiene Association Annual Meeting, April 25, 1959, Chicago, Illinois

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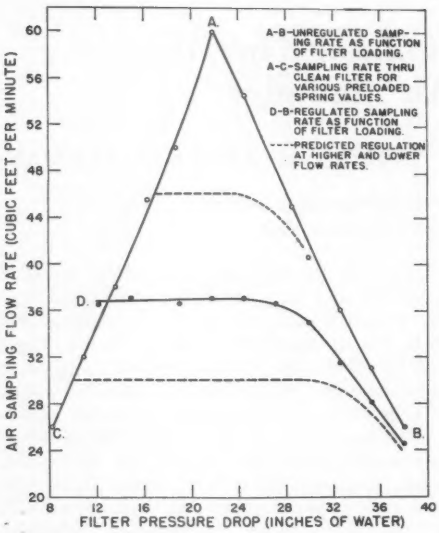
A-B-UNREGULATED SAMPLING RATE AS FUNCTION OF FILTER LOADING.
A-C-SAMPLING RATE THRU CLEAN FILTER FOR VARIOUS PRELOADED SPRING VALUES.
D-B-REGULATED SAMPLING RATE AS FUNCTION OF FILTER LOADING.
PREDICTED REGULATION AT HIGHER AND LOWER FLOW RATES.
AIR SAMPLING FLOW RATE (CUBIC FEET PER MINUTE)
FILTER PRESSURE DROP (INCHES OF WATER)
A.
B.
C.
D.

FIGURE 1. Hi-volume sampler performance with and without regulation.

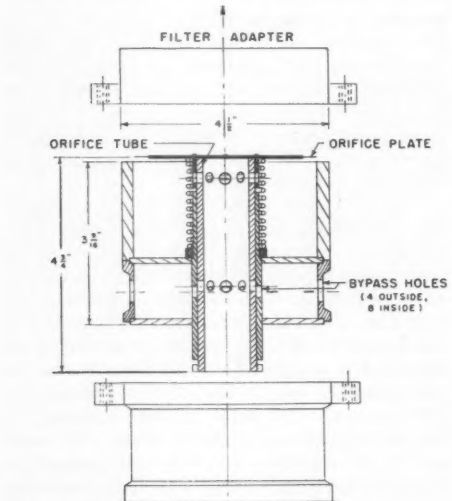

FIGURE 2. Bypase regulator, cross-section.

control chamber behind the orifice plate at the static pressure of the orifice tube. The control pressure developed across the orifice plate acts against the spring to maintain the plate-tube assembly at an equilibrium position. Bypass air is controlled by the positioning of the plate-tube assembly which varies according to the airflow through the filter. The bypass regulator is mounted in an enclosure (Figure 3) which serves as a weather-proof shelter self-contained shipping case, and a sound-proof chamber.

The regulator was tested using a clean filter which was allowed to increase its resistance by means of a simulated variable loading. Incremental readings of flowrate and corresponding pressure drops were taken. The data indicated regulation at 33 cfm over a pressure drop range of 13 inches of water (starting at about 13 inches of water with a clean filter). The flowrate was maintained constant over this range within ±4% of the regulation level.

Field tests in which flowrate measurements were made with accumulated loadings of dust showed the above regulation over a range of 47 to 167 hours of sampling time during which 355 to 910 mg, respectively, of dust was collected. A sampler without regulation was run concurrently alongside the regulated sampler and its flowrate in the corresponding periods dropped from 61 to 12 cfm and from 63 to 18 cfm. The shorter period of time over which regulation was maintained for a small loading is indicative of the agglomerating and tarry type of dust which more effectively restricts the air flow.

Series Regulator

The series resistance regulator (Figure 4) is an improvement on the bypass regulator. It is compact and easily applicable to the high-volume air sampler as an insert in the throat of the filter adapter, leaving the system otherwise physically intact.

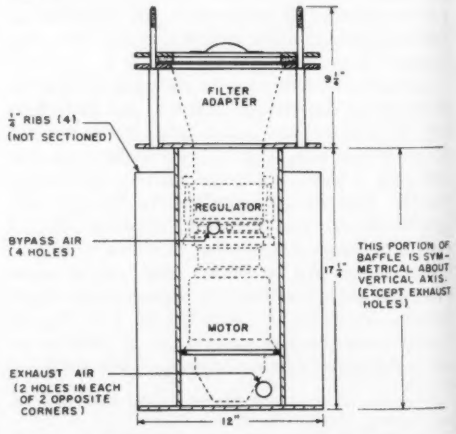
FILTER ADAPTER
RIBS (4) (NOT SECTIONED)
REGULATOR
BYPASS AIR (4 HOLES)
THIS PORTION OF BAFFLE IS SYMMETRICAL ABOUT VERTICAL AXIS. (EXCEPT EXHAUST HOLES)
MOTOR
EXHAUST AIR (2 HOLES IN EACH OF 2 OPPOSITE CORNERS)
12"

FIGURE 3. Bypass regulator, cross-section of mounting baffle.

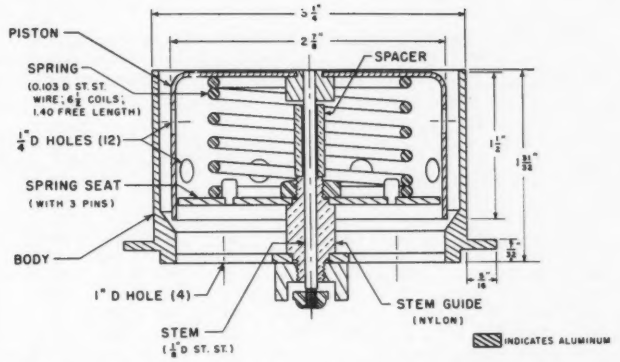

FIGURE 4. Constant flow regulator, sectional view with piston partially raised.

This insert regulator simply consists of a spring loaded piston valve which provides an annular opening between its skirt and the wall of the regulator body in which it is contained. In operation the airflow pressure on the piston surface opposes the force of the compressed spring. A position of equilibrium is established, determining the effective annular opening and the resulting airflow resistance of the regulator. Any tendency for air flowrate change is counteracted by a corresponding change in the orifice opening. Thus, an increase in filter resistance tending to reduce the flowrate causes the regulator resistance to decrease as a result of an increase in its orifice area. Constant flowrate or regulation is effectively achieved by maintaining the sum of filter and regulator resistance constant.

The performance of the insert regulator is shown graphically (Figure 1) in relationship to the performance of the sampler using the fiber glass filter (8- x 10-inch sheet). The Curve A–B is the flowrate characteristic of an unregulated sampler as a function of filter loading. The pressure drop in inches of water is used to express the filter resistance as a result of increasing particulate loading.

When the sampler is used with a regulator, the added resistance of the regulator orifice reduces the flowrate thru the initially clean filter. The greater the resistance of the regulator orifice, corresponding to smaller flow area as a result of lighter spring loadings, the lower is the air flowrate thru the clean filter. Curve C-A represents flowrate-pressure drop values of a clean filter for various regulator spring loadings. The developed regulator gave initial flowrate of about 37 cfm (point D) which came sufficiently close to the design value of 35 cfm. The flowrate characteristic of the sampler with this regulator (Curve D–B) showed excellent regulation. Over a range of about 16 inches of water of filter loading, the flowrate was constant within one cubic foot per minute.

The regulation curve D–B (Figure 1) is one of a family of similar curves which fall in the "zone of regulation" represented by the area within curves C–A and A–B. The regulator may be designed with other values of prestressed spring loadings to give regulation at lower or higher flowrates (dotted curves) and the range or regulation will be correspondingly more or less. This has been confirmed by actual tests using springs designed with various preload values. At high flowrates the range of regulation is small and does not allow for regulation over long sampling intervals or at high dust loadings. The range of regulation is large at low flowrates which, however, defeat the objective of high-volume air sampling. Furthermore, there is a minimum flowrate (approximately 25 to 30 cfm) required to cool the motor under continuous operation. The choice of a particular flowrate at which one wishes to regulate is a compromise between these opposing considerations.

Six production prototypes of the insert regulator were tested in the field for 24 hour sampling intervals corresponding to Network procedures. In these tests an unregulated sampler was run concurrently alongside a regulated sampler for comparative evaluation. The results on the six units tested (Table I) showed a final to initial flowrate ratio at the end of the 24 hour period in the ranges of 38 to 59% and 87 to 101% for the unregulated and regulated samplers, respectively. Two significant conclusions may be drawn from Table I. First, assuming that regulated samplers yield the true average dust concentration, the deviation of concentration using current practice of averaging initial and final flowrate from true concentration is in most cases not so great as to

TABLE I

Field Data on Six Production Prototype Series Regulators

Test	Flowrates (cfm)						Sampled volumes (m³)			Collected dust (mg)			Dust conc. (μg/m³)		
	No Reg.			Reg.			No. Reg.	Reg.	Reg. / No Reg. %	No Reg.	Reg.	Reg. / No Reg. %	No Reg.	Reg.	Reg. / No Reg. %
	Initial	Final	Final / Initial %	Initial	Final	Final / Initial %									
1	60.0	28.5	48	38.0	35.5	94	1794	1537	86	294	246	84	164	160	98
2	56.0	33.0	59	43.0	40.0	94	1891	1804	96	575	496	86	304	275	90
3	60.0	28.0	47	37.0	37.5	101	2010	1500	75	281	215	76	140	144	103
4	60.0	28.5	48	41.5	36.0	87	1794	1602	89	294	279	95	164	174	106
5	56.5	30.0	53	38.0	37.0	97	1810	1624	90	141	103	73	78	63	81
6	57.0	21.5	38	43.0	41.5	97	2069	2234	108	306	212	69	148	95	64

impair confidence in the large body of data thus obtained, four of the six values being within 10% of the true value. Second, since deviations as great as those of tests 5 and 6 can occur, there is good reason to convert unregulated samplers to the regulated type as rapidly as this can be accomplished. Further, it is pointed out that the six tests were for relatively extreme concentrations of clogging type dusts and as such are not representative of the majority of the samples occurring in the Network. Therefore the errors introduced by these situations will have even less significance when applied to the Network data as a whole.

Preliminary measurements without the use of regulators were made in a test of 15 loaded filters obtained from the Network, in which the pressure drop across each filter was measured to arrive at an estimate of the range of added pressure drop which might be realized in 24 hours of sampling with regulators. Results showed that 10 of the 15 had pressure drops within the range of regulation (16 inches of water) and all were within 20 inches of water. It must be realized that these values are higher than those which would have been obtained with regulated sampling, because less particulate would have been collected as a result of sampling a smaller volume of air. Additional data from regulated sampling necessary for a more accurate evaluation is being planned as part of a continued study of high-volume air sampling and dust concentration measurements.

Summary

Both theoretical calculations and experimental tests under field conditions show that a significant difference can occur in the values of dust concentration obtained by high flowrate regulated samplers and those not so regulated. Since this indicates the desirability of converting unregulated samplers to the regulated type, two regulators, each operating on a different principle, have been developed to maintain a constant flowrate (approximately 35 cfm) of air in a high-volume air sampler as the particulate loading increases. The series regulator, being compact and simple in construction, is immediately applicable to the high-volume air samplers as an insert in the filter adapter. Both regulators showed satisfactory operation, having regulation within ±4% over a pressure drop range of 13 to 16 inches of water.

Acknowledgments

The authors express their appreciation to their staff members, Mr. Daniel R. Allen, A.San.E., Mr. Alan Cohn, E.E., and Mr. Charles Norris, electronic technician, for their assistance in construction and performance evaluation of the regulators.

Appendix A

Flowrate as a Function of Time

Let q and c represent, respectively, the instantaneous values as functions of time of the flowrate and the particulate concentration sampled by the filter. The weight of particulate deposited on the filter in an infinitesimal time is

$$dW = qcdt \tag{1}$$

Assume that the incremental change of airflow is proportional to the incremental weight of particulate deposited on the filter. Then the differential equation of a clogging filter is

$$-dq = KdW = Kqcdt \tag{2}$$

where K is a characteristic of the filter, and the minus sign denotes clogging of the filter by dW. Integrating:

$$q = q_0 e^{-\int Kcdt} \tag{3}$$

where q_0 is the initial flowrate.

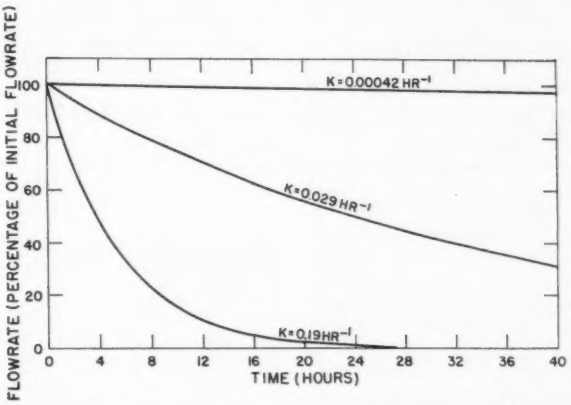

FIGURE 5. Sampling rate as a function of time with constant concentration of atmospheric particulates.

If c is independent of time and equal to a constant value, the flowrate variation then becomes a simple exponential function of time. Thus, for a particular filter, progressively larger values of c cause more and more drastic drop-off in airflow (Figure 5).

Note that for low values of K, the exponential approximates a straight line so that the assumption of a linear decrease in flowrate is not greatly in error.

Appendix B

Flowrate and Concentration as Functions of Time

Let the instantaneous dust concentration in atmospheric air at the sampler be expressed as a general function of time, $c = f(t)$. The average concentration over a period of time will be the integral of this function divided by the time interval, i.e.

$$\bar{c} = \frac{\int_{t_1}^{t_2} c\,dt}{t_2 - t_1} \tag{4}$$

where

$\bar{c}$ = average concentration
t = time
c = instantaneous concentration

In the ordinary concept of measuring the average concentration of particulate in the air, an implicit assumption is made that the sampling rate is constant and as a result, does not appear in Equation 4. When the air is sampled at a rate which is not constant but instead is a function of time, then the integral of the concentration will involve the flowrate as a function of time, $q = q(t)$, such that the average concentration, $\bar{c}'$, is expressed as:

$$\bar{c}' = \frac{\int_{t_1}^{t_2} cq\,dt}{\int_{t_1}^{t_2} q\,dt} \tag{5}$$

If sampling measurements are to give an accurate measure of the true average concentration, then $\bar{c}$ must be identical to $\bar{c}'$. This is immediately apparent when either the concentration is constant or the flowrate is constant. Otherwise the identity may only exist under a unique and, most likely, unpredictable set of conditions.

On the other hand a representative sample is necessary if a quantitative evaluation is to be made of a component pollutant. In such a case, although the concentration of the total pollutants may be for all practical purposes constant, variation in the concentration of the component of interest necessitates sampling at a constant rate. Otherwise, with any significant drop in flowrate, the concentration of the component pollutant will be calculated in error on the basis of the same argument given for the pollutants as a whole.

In practice the net weight of particulate collected, W, is measured and the average flowrate, $\bar{q}$, is taken as the arithemetic average of the initial, q_1, and the final, q_2, flowrates, i.e.

$$\bar{q} = \frac{q_1 + q_2}{2} \tag{6}$$

The average concentration, $\bar{C}$, is calculated as

$$\bar{C} = \frac{W}{\bar{q}(t_2 - t_1)} \tag{7}$$

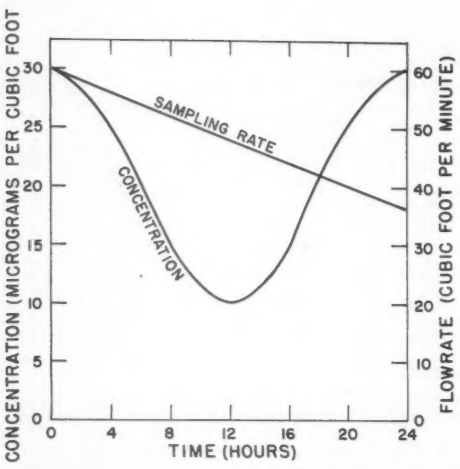

FIGURE 6. Atmospheric particulate concentration and sampling rate as function of time.

This value of $\bar{C}$ is an accurate measure of $\bar{c}$ only to the extent that Equation 7 is identical to Equation 4, i.e.

$$\frac{W}{\bar{q}(t_2 - t_1)} \equiv \frac{\int_{t_1}^{t_2} c\,dt}{t_2 - t_1} \tag{8}$$

This identity is probably not often realized in field practice, a point which can best be illustrated by considering representative field conditions.

Consider a sampling interval of 24 hours and assume the concentration as a function of time is approximated by the expression

$$c = A(2 + \cos Bt) \tag{9}$$

This would represent conditions in which the concentration is maximum at the start and end of the sampling period (Figure 6) and is representative of the diurnal variation which occurs. The average concentration calculated using Equation 4 is 20 $\mu g/ft^3$ or 706 $\mu g/m^3$ where

$$A = 10\ g/ft^3$$

$$B = \frac{\pi/12}{HR}$$

For simplicity of calculation assume the flowrate decreases linearly with time as the load increases on the filter, as follows:

$$q = a - bt \tag{10}$$

where (Figure 6)

$$a = 60\ \text{cfm}$$
$$b = 1\ \text{cfm/HR}$$

Substituting in Equation 5, the measured concentration is

$$\bar{c}' = \frac{\int_0^{24} A(2 + \cos BT)(a - bt)\,dt}{\int_0^{24} (60 - t)\,dt} \tag{11}$$

giving a value of 26.7 $\mu g/ft^3$ or 943 $\mu g/m^3$.

This comparison illustrates for the conditions assumed, the departure of the calculated from the true average. This difference indicates that the collected sample is not entirely representative of the particulate in the atmosphere, a factor illustrated by a qualitative appraisal of Figure 6. Pollutants present in the earlier part of the interval are collected in a greater amount than those present in the latter part of the sampling period.

It is conceivable that the variation of airflow and particulate concentration with time is often quite small during a sampling period. In this case, errors due to these effects will also be small. More research is needed to properly assay the probable magnitude of these fluctuations under all sampling conditions. Under any circumstances, however, constant flow regulation eliminates errors in sampling due to variable particulate concentration and progressive filter clogging.

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The Acute Toxicity of Cyanogen

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Introduction

THIS study was undertaken to supplement the paucity of experimental data on the acute toxicity of cyanogen existing in the literature. The only two references to experimental work found by the authors were those reported by Bunge[1] in 1880 and by Burckhardt[2] in 1913 as reviewed by Flury and Zernik[3] in 1931. Due to the lack of clinical data and animal research on which to base their surveys, reviewers have presumed cyanogen to be "exactly"[4] as toxic, "probably as toxic",[5] "somewhat less toxic",[6] and "considerably less toxic"[3] than hydrogen cyanide. This divergence of opinions plus the absence of quantitative information on the skin absorption and the threshold levels of odor and irritation prompted this investigation. These preliminary experiments are presented as a step toward a better understanding of the actual role of cyanogen in industrial hygiene.

Cyanogen, also referred to as oxalic nitrile, ethane dinitrile, or prussite, is used primarily in organic synthesis. It is stated to hydrolyze to yield one molecule of hydrogen cyanide and one of cyanate.[4] This is the basis for the supposition that cyanogen is comparable in toxicologic effect to hydrogen cyanide. However, the exact metabolism of cyanogen is not known. It is a gas at normal temperatures and pressures and where mentioned in the text it is considered in its gaseous state. Some pertinent properties of both cyanogen and hydrogen cyanide are given in Table I.

Methods

The study is divided into three parts, the acute inhalation toxicity, the skin absorption toxicity, and the odor and irritation threshold levels of cyanogen. The first two parts employed a two-foot-cube galvanized metal exposure chamber, the third included in addition, an 1185 cubic foot sealed room. Each was operated under static gas exposure conditions. The cyanogen gas used contained less than 0.5% contaminants such as nitrogen, chlorine and cyanogen chloride. The various concentrations of cyanogen were attained by measuring the required volume of the gas over mercury in a graduated, gas sampling tube and introducing it into the exposure space by displacement of the mercury. In raising the concentration to the desired level a portion of each exposure period was expended. The lengths of these build-up periods, which varied with the volume of gas to be admitted at the established rate of flow, are tabulated in the appropriate tables.

Acute Inhalation Toxicity. Male albino rats in groups of six whose weights averaged 135 grams were housed in two wire mesh cages within the chamber and exposed to a total of six different concentrations and six different time periods. A plexiglas door, bolted to the chamber, both sealed the unit and permitted the observation of the enclosed rats.

Skin Absorption Toxicity. Four male albino rabbits whose weights averaged 4.5 pounds were closely clipped of their fur, restrained in a wooden stock, and placed in the chamber. An especially designed door, through which the rabbits' heads extended into glass jars maintained under positive air pressure, prevented the rabbits from breathing cyanogen while their bodies were being exposed and also made observation of the heads of the rabbits possible. The bodies of the rabbits were exposed to a cyanogen concentration of 10,000 ppm (parts per million by volume) for a period of eight hours.

Odor and Irritation Threshold Levels. Two types of exposures were employed, one in which humans were exposed to the gas in the sealed room, the other in which humans attempted to detect the odor of the gas by breathing through a tube attached to the small chamber.

Three tests were performed utilizing the sealed room, one at eight ppm exposing three males and two females for six minutes and two at 16 ppm exposing four males and three females for six and eight minutes. The ages of the subjects ranged from 21 to 65 years, and all were in good health except one who had mild cold symptoms. As part of the first test at 16 ppm one of the subjects was withheld from the sealed room until the other subjects had completed their exposure, at which time he entered as the others departed. He was exposed to the resulting concentration for six minutes.

Four human subjects, three males and one female, attempted to detect any odor of the gas drawn from a sampling tube connected to the

TABLE I

Properties of Cyanogen and Hydrogen Cyanide

	Cyanogen	Hydrogen Cyanide
Formula	NCCN	HCN
Molecular weight	52.04	27.03
Color, state	colorless, gas	colorless, liquid
Boiling point	−21°C	26°C
Vapor density (air = 1)	1.67	0.94
Vapor pressure	78 psig at 20°C	25.3 psig at 18.1°C
Limits of inflammability (%)	6.6 to 42.6	5.6 to 40

TABLE II

Effects of the Acute Inhalation Exposures of Cyanogen Upon Male Albino Rats

Concentration of Cyanogen (ppm)	Concentration of Cyanogen (mg/m³)	Average Temp. (°C)	Length of exposure (minutes)	Length of build-up period (minutes)	Mortality ratio (dead/dosed)	Initial average weight of rats (grams)	Average weight gain after 14 days (grams)
4000	8571	22.8	7.5	3.0	3/6	162	44
4000	8508	25.0	15	3.0	6/6	156	—
2000	4223	27.2	7.5	1.5	0/6	126	55
2000	4207	28.3	15	1.5	6/6	121	—
1000	2111	27.2	15	0.5	0/6	123	52
1000	2115	26.7	30	0.5	6/6	123	—
500	1066	24.4	30	0.3	0/6	134	49
500	1054	27.8	45	0.3	6/6	122	—
400	851	25.0	45	0.25	0/6	144	46
400	851	25.0	60	0.25	6/6	137	—
250	537	22.2	60	0.15	0/6	160	59
250	533	24.4	120	0.15	4/6	127	38
Control	—	—	—	—	0/6	167	53

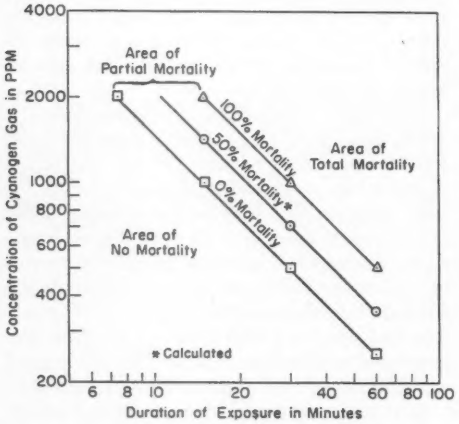

FIGURE 1. Inhalation toxicity of cyanogen in rats.

chamber where concentrations of 50, 100, and 250 ppm were produced.

Results

Acute Inhalation Toxicity. A summary of the experimental conditions and results of the inhalation of cyanogen by rats is given in Table II. The mortality data plus calculated LC_{50}'s are graphically presented on a log-log scale in Figure 1. The graph provides a series of curves that delineate areas of time-concentration exposures which kill all rats exposed, a portion of the rats exposed, and a third area in which no deaths are likely to occur.

Based upon observations of the rats during their exposure the prime effects were asphyxiation, lachrymation, upper respiratory tract irritation, and the pink coloration of the noticeable skin. The typical signs and symptoms exhibited chronologically by the rats were: blinking eyes, rubbing of forepaws over eyes and snout, huddling together with inactivity, slow gasping, tearful eyes, yellow fluid dripping in appreciable quantities from nares and mouth, restless and panic type movements, accentuated and poorly coordinated motions, bright pink coloration of the skin, labored breathing, deeper and more frequent gasping, tremors, sluggishness, prostration, shallow breathing, and death.

Two of the four rats that survived the exposure, to 250 ppm for 120 minutes, eventually died during a 14-day holding period. One died after seven hours, exhibiting signs of central nervous system damage from the end of the exposure until death; the other died after seven days and did not reveal any signs of physiological malfunction. These were the only delayed deaths in the entire series of exposures.

The only notable effect of the exposure on the weights of the exposed rats was that the two groups surviving with partial mortality produced the lowest average weight gains. The weight data are included in Table II.

None of the rats, neither after experimental death nor after the holding period, presented any gross pathological lesions at autopsy.

Skin Absorption Toxicity. The rabbits displayed no macroscopic effects from the exposure of their skin to 10,000 ppm of cyanogen for eight hours. No gross pathological lesions were apparent at autopsy.

Odor and Irritation Threshold Levels. A summary of the odor and irritation effects of cyanogen upon human subjects exposed to the gas in the sealed room is found in Table III. In none of the tests was any odor detectable and in the eight

TABLE III

Odor and Irritation Effects of Cyanogen upon Human Subjects

Concentration (ppm)	Length of exposure (minutes)	Length of build-up period (minutes)	No. of subjects	No. of subjects experiencing effects		
				Odor	Irritation	
					Eye	Nasal
8	6	0.5	7	0	0	0
16	6	3	5	0	5	4*
16	8	3	7	0	7	7

* The subject not experiencing nasal irritation had mild cold symptoms prior to the exposure.

ppm test no sign of irritation was experienced. During the 16 ppm tests the subjects felt eye irritation almost immediately after the concentration in the room had been raised to the desired level. This effect was either perceived simultaneously with or shortly before the occurrence of nasal irritation. Both eye and nasal irritation persisted for several minutes following the completion of the exposure. The subject who entered the room at the conclusion of the 16 ppm exposure experienced the same type of effects as the original subjects.

None of the subjects who attempted to smell the gas sampled from the chamber was able to detect any odor at cyanogen concentrations of 50, 100, and 250 ppm.

Discussion

Although additional experimental work is necessary to make a comprehensive quantitative comparison between the toxic effects of cyanogen and hydrogen cyanide the results of this study indicate that cyanogen is less toxic. In a dissertation reviewed by Flury and Zernik[3] work is described in which an exposure of 110 ppm of hydrogen cyanide for one and one-half hours was required to kill rats. Also, Grubbs[7] reported that a one-hour exposure to 240 ppm of hydrogen cyanide killed most rats and 480 ppm killed all rats in 15 minutes. The present study has shown that rats withstood 250 ppm of cyanogen for two hours with only partial mortality and 500 ppm for 30 minutes with no deaths. In addition, the capacity of the rats in this study to tolerate the excessive concentrations of 1000 and 2000 ppm of cyanogen for periods of approximately 15 and 7.5 minutes, respectively, points toward a lower toxicity.

Further information on the toxicity of hydrogen cyanide is given in Henderson and Haggard[8] and in a recent review by Wolfsie and Shaffer.[9] In a number of toxicity tables the "rapidly fatal" concentration of hydrogen cyanide is given as 3000 ppm. The basis for this figure is apparently a table by K. B. Lehmann, published by Kobert[10] in 1912. In this table, the following data on the effects of hydrogen cyanide on humans is presented:

The Concentrations:		
Causing rapid death in men and animals	about 0.3/1000	(300 ppm)*
Causing illness dangerous to life in ½ to 1 hour	0.12–0.15/1000	(120–150 ppm)
Tolerated without serious disturbance for ½ to 1 hour	0.05–0.06/1000	(50–60 ppm)
Causing slight symptoms with many hours of action	0.02–0.04/1000	(20–40 ppm)

* The equivalents within the parenthesis are the authors'.

In various reviews the above data have been referred to as milligrams per liter and in others the rapidly fatal dose has been misinterpreted as 0.3 per 100 or 3000 ppm. In other words, the figure 3000 ppm for "rapidly fatal" is an error in translation as the figure in the table by Kobert[8] is given as "about 0.3 ‰" that is, 0.3 part per *thousand* or 300 ppm.

Summary

A series of experiments were performed to provide current data on the acute toxicity of cyanogen. A time-concentration graph was developed that delineates areas of total, partial, and no mortality of male albino rats for exposures to concentrations ranging from 250 to 2000 ppm. It was determined that male albino rabbits could endure an exposure to their skin of 10,000 ppm for eight hours without any apparent detrimental effects. Human subjects experienced nasal and/or eye irritation upon exposure to concentrations of 16 ppm but no effects from a concentration of eight ppm. Human subjects were unable to detect any odor from concentrations of cyanogen as high as 250 ppm.

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GORDON RESEARCH CONFERENCES

THE GORDON RESEARCH CONFERENCE on Toxicology and Safety Evaluations will be held August 15–19, 1960 at Kimball Union Academy, Meriden, New Hamshire. David W. Fassett is Chairman and Frank R. Blood is Vice-chairman this year. An exceptional program of discussions of toxicology related to drug evaluations, industrial exposures, pesticide residues, and carcinogenesis has been arranged. One session will be devoted to the use of behavioral patterns in animal experiments.

The conferences were established to stimulate research in universities, research foundations and industrial laboratories. This purpose is achieved by an informal type of meeting consisting of scheduled lectures and discussion groups. Sufficient time is available to stimulate informal discussions among the members of the conference. Meetings are held in the morning and in the evening, Monday through Friday, with the exception of Friday evening. The afternoons are available for recreation, reading or participation in discussions. This type of meeting is a valuable means of disseminating information and ideas to an extent that could not be achieved through the usual channels of publication and presentation at scientific meetings.

Attendance at the conference is only by application. Individuals interested in attending this conference are requested to send their application to the Director before June 15, 1960. All applications must be submitted on the standard form which may be obtained by writing to the office of the Director. For full details of costs, selection and other matters, as well as application forms, write to W. George Parks, Director, Department of Chemistry, University of Rhode Island, Kingston, Rhode Island.

What Do You Mean by Normal Hearing?*

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THE standards and terminology of hearing testing and evaluation were established over twenty years ago. In the intervening period, there have been developments which were not anticipated and hearing evaluation has taken on new significance. It is time that current standards were examined to learn what inadequacies exist, what misunderstandings have arisen, what is being done about them and what further changes are needed.

There seems no better avenue of inquiry than to ask, "What do you mean by normal hearing?" The answer to this question hinges on the sense in which the word "normal" is used. Probably, most interpret normal as meaning occurring naturally, or the usual condition or the like. This is undoubtedly the sense in which it is understood by the general public. Some may realize that the question may use normal in the biological sense and feel some uncertainty as to exactly what meaning is intended. At best the question is equivocal. It merits further consideration since the answer has an important bearing on the occupational hearing-loss problem.

In order to clarify the ambiguity which exists, the authoritative definition of the word normal as applied to hearing will be explored at some length. Referring to the American Standard for audiometers,[1] the following definition is found:

> "The normal threshold of audibility for air conduction at a given frequency is the modal value of the minimum sound pressures at the entrance to the ear canal which produces a pitch sensation in a large number of normal ears of individuals between 18 and 30 years of age. The threshold values accepted for the purpose of this specification shall be those of the National Health Survey 1935–6."

From this definition, it appears that the audiometric normal is the faintest sound most commonly heard by a group of young people studied in the National Health Survey. But it is not clear what restrictions were imposed on members of the group other than that clinical findings be negative.

Referring now to a report of the National Health Survey,[2] it is learned that:

> "Two rules were employed in segregating audiograms for inclusion in the group arbitrarily defined as representing normal hearing: audiograms were selected only for persons (a) having a clinical history of no noticeable difficulty in hearing speech with either ear, and (b) whose air conduction audiograms for both ears do not exceed a variation of 20 decibels (db) on the eight tones from 64 to 8192 cycles. . . . Among the 4662 persons having a clinical history of normal hearing for speech in both ears, there are 1242 persons (27 per cent of the 4662) whose air conduction audiograms for both ears do not exceed a variation of 15 or 20 db on eight tones."

This report, by its own terminology, describes the definition of normal hearing as arbitrary. How true this is becomes obvious when it is learned that less than 15% of the total sample qualified for inclusion in the normal group under the National Health Survey rules. The normal group became even more select when the age restriction of the American Standard Association was imposed.

It should now be clear that normal hearing is defined in such a special way that neither the common conversational meaning nor the biological sense of the word is at all descriptive of the concept. It is unfortunate that the word normal was used to describe such a restricted group as many are misled by the term.

It is bad enough that normal was used to describe the hearing reference zero; but to make matters worse, the term hearing loss was designated by an American Standard to describe variations from this zero. The difficulties which have arisen in use of hearing loss have been described[3] by three otologists of national prominence as follows:

> "The familiar term 'hearing loss' includes three quite distinct concepts, and much confusion and many unnecessary arguments have occurred in court rooms, in committee rooms and in clinics because of this semantic monstrosity. These three concepts are (1) the otological meaning: A symptom indicating an abnormal condition of hearing, (2) the audiological meaning: the status of hearing as measured by a reading in decibels on the hearing loss dial of an audiometer, and (3) the common

* Presented at the Twentieth Annual Meeting of the American Industrial Hygiene Association, Chicago, Illinois, April 29, 1959.

sense meaning: *a change for the worse* in sensitivity of hearing. It has been particularly difficult in medico-legal situations to reconcile the second meaning with the other two and to explain that the normal range of hearing extends from a hearing loss of minus ten to a hearing loss of plus ten or fifteen decibels. It is hard to convince a jury that a man can have a hearing loss of ten decibels when his hearing may actually never have changed at all. It has been very difficult and cumbersome, also, in our own writings to distinguish clearly between the *status* of hearing, to which disability of hearing and physical standards for military duty, etc., are related, and a *change in status* of hearing, which is the central concept of monitoring audiometry."

From the foregoing, it is obvious without further comment that continued use of the term hearing loss for all three concepts mentioned is impractical.

To further compound the difficulties arising from present American Standard definitions, several formulas are in use for estimating percentage impairment on the basis of hearing loss (status of hearing) depicted by an audiogram. At the present, the majority of such calculations are done by either the Fletcher 0.8 formula or the AMA (1947) formula. Without going into detailed discussion of these formulas, it is sufficient for present purposes merely to point out that each of these embodies the basic premise that normal hearing as presently defined (zero hearing loss) is the point at which impairment begins. Each formula, on the basis of its own theoretical considerations, provides a method for assigning a percentage impairment to hearing loss (status) beyond this point. Thus, the arbitrary definition and misleading terminology have helped to produce a practical problem of much importance.

Others have realized that these problems exist and have taken steps resulting in at least partial solutions. The three otologists mentioned earlier have offered an excellent suggestion for eliminating the confusion of meaning surrounding the term hearing loss[3] which is quoted below:

"We shall use, and we recommend for general usage, three different terms for three different although related meanings of 'hearing loss.'

1. *Hearing level* is the deviation in decibels of an individual's threshold of hearing from the American Standard value for the reference zero for audiometers. This is a measure of the *status of hearing.* It is read directly on the 'hearing loss' scale of an audiometer. To be completely explicit, we should say 'threshold hearing level,' meaning the number of decibels above the sound-pressure level that corresponds to the reference threshold of hearing. In general, however, the shorter phrase 'hearing level' should be adequate.

"The military physical standards of acceptable hearing and some of the 'monitor limits' that are to be described later are now stated in terms of 'hearing loss,' but in accordance with the new usage here proposed they should be stated in terms of 'hearing level.'

"Hearing level' refers to a single measurement made with a standardized instrument and referred to an arbitrary zero reference level. Larger numbers indicate that more acoustic energy is needed to reach the threshold of hearing. The term is analogous to the physicist's 'sound pressure level.' Both specify a level relative to a reference level, but the reference for hearing level is different at different frequencies.

"The term *speech hearing level* or 'hearing level for speech' is a convenient designation for the average of the hearing levels for the frequencies necessary for the understanding of speech.

2. "*Hearing loss* will be used only to refer to the symptom of reduced auditory sensitivity, as in the phrases 'conductive hearing loss,' 'noise-induced hearing loss,' etc. These examples illustrate the otologist's automatic concern with the question of the mechanism of a hearing loss, its cause, and its possible cure. 'Hearing loss' for the otologist is the modern substitute for the old phrase 'partial deafness' and means almost exactly the same thing as 'auditory impairment.' It may also be used in a general way to refer to the process of losing auditory sensitivity, as in the phrase, 'he suffered a hearing loss.'

3. "A *threshold shift* is the deviation in decibels from an individual's own previously established reference audiogram. It is a *measure of change in the status of hearing.* It is the term we shall usually employ instead of the more familiar 'loss of hearing.' Unless otherwise specified, it is assumed that the shift of threshold is upward to a higher hearing level, meaning that the change in hearing is a change for the worse. A change for the better will usually be termed a recovery."

The committee of the American Standards Association appointed to rewrite the standard for audiometers will probably discontinue use of the terms normal and hearing loss and adopt terminology in line with that suggested above. But the committee also will likely revise the audiometric zero level to conform to that used in Europe. This change will shift the zero level at each frequency to near the present minus ten level so that the practical result will be to add about 10 deci-

bels to all readings. This step seems unnecessary and unwise. A great deal of inconvenience and confusion would be suffered by the many persons who must consider audiograms but have the barest understanding of their significance, not to mention the effect on existing statutes and administrative rulings. Only the relatively few persons who must compare American audiograms with European ones would benefit. But, generally, this group is thoroughly competent to understand and make the necessary corrections and is currently doing so with ease. On the whole, the disadvantages of the zero change far outweigh the advantages.

Recently, the Subcommittee on Noise of the American Academy of Opthalmology and Otolaryngology has announced a new method for estimation of hearing impairment[4] which seems much superior to the methods presently used. Without going into details of the formula, its chief advantage is that it attaches no significance to average hearing levels at 500, 1000 and 2000 cps of less than 15 db which tends to cancel the effects of having a normal corresponding to very acute hearing. The announcement of this formula is a significant development which is to be commended. But it is not considered the last word even by its authors who refer to it as an interim method in anticipation of future revisions.

Helpful as the new formula may be, it is of little aid in establishing causal relationship between history and condition of hearing. It merely enables one to make a reasonable quantitative statement about the status of hearing in terms of impairment. It does not enable one to tell from a single audiogram whether an unusual degree of deafness exists. Nor does it enable one to state whether a threshold shift revealed by serial audiograms is unusually large indicating that an injury has occurred. Such determinations are best made by comparison with a population indistinguishable in every respect from the case at hand except for possible hazardous exposure. This is merely a statement of the statistical principle that little significance may be attached to an observed variation as long as such a variation is quite common. There is too much risk that the common variation may be a chance occurrence. The variation must be sufficiently large to be of fairly rare occurrence before it is to be looked upon as an oddity.

Applying these thoughts to hearing loss which may have resulted from occupational noise exposure, it is clear that causal relation cannot be established reliably wihout some knowledge of what the hearing status would have been in the absence of the exposure. For example, if the hearing status of the case in question is such that 50% of the unexposed population his age is as bad or worse, it would be very risky to state that the loss was due to occupational noise exposure. There would be a 50-50 chance that his hearing level would have fallen in this range in the absence of any exposure. It is only because of unrealistic standards that a hearing impairment might be found or calculated by some formula in the first place.

By scientific and intuitive standards, most would be reluctant to designate the man's hearing status as abnormal, much less state causal relation to noise exposure unless the hearing level was rare for the age. How rare it should be is a matter of individual opinion. The degree of rarity may be stated in terms of the percentage of the unexposed population which has hearing as bad or worse, even though there has been no exposure to hazardous noise. At the 10% level some persons would accept the case as an abnormality and consider causal relation to occupation possible since only 10%, or 1 out of 10, unexposed persons would be expected to have this degree of deafness. That is, the odds are 1 in 10 that the audiogram would have fallen in this range without any exposure. Rather than make a flat statement that the hearing status was or was not normal, the statistician might say "this hearing loss is significant at the 10% level" meaning that the chances are 1 in 10, or 10%, that it would have prevailed in the absence of any exposure. This also means that if he makes numerous predictions on variations significant at the 10% level, he may expect to be correct 90% of the time and in error only 10% of the time. Depending primarily on the cautiousness with which an individual makes positive statements, he might require a level of significance of 5%, 1% or even less before stating that a true abnormality existed and causal relationship was possible.

For quantitative application of this idea, let us now refer to hearing data obtained on the male office workers studied in the Wisconsin State Fair Hearing Survey.[5] Presumably, none of these workers had significant exposure to hazardous industrial noise. Dr. Aram Glorig, who directed the Wisconsin survey, feels that there is some bias in the sample which causes the group of Wisconsin office workers studied to show poorer hearing than might be expected of office workers generally. However, the data on the Wisconsin office workers is the best available currently on the hearing acuity of a population having minimal exposure to industrial noise, so this data will be used for illustration.

The cumulative distributions of average hearing levels at 500, 1000 and 2000 cps for the right ears of the Wisconsin office workers is shown by

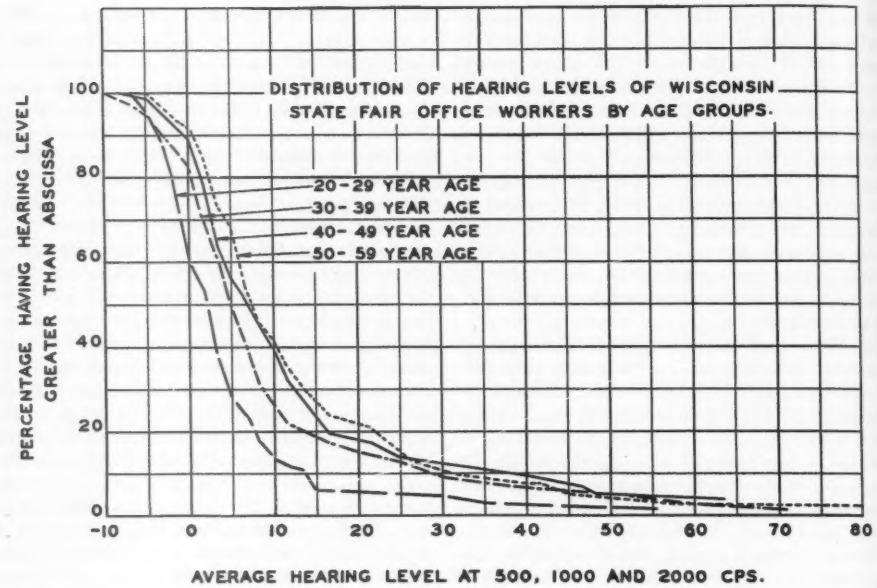

FIGURE 1.

TABLE I

Hearing Impairments of Office Worker Group of the Wisconsin State Fair Hearing Survey as Calculated by the AAOO Formula.[4]

Age range in years	Total number of cases	Number of cases impaired	Average binaural impairment
20–9	69	10 or 14%	10.4%
30–9	87	18 or 21%	18.9%
40–9	66	16 or 24%	14.0%
50–9	63	18 or 29%	20.4%
60–9	16	10 or 62%	—

age groups in Figure 1. These curves show on the vertical scale the percentage of cases having an average hearing level at 500, 1000 and 2000 cps greater than the amount shown on the horizontal scale. Considering the 20–29 year age group, for example, it is seen that 50% had average hearing levels greater than 2 db and that 10% had average hearing levels greater than 13 db. For, the 50–59 year age group, 50% had average hearing levels greater than 7 db and 10% had average hearing levels greater than 31 db. From Figure 1, it is apparent that the majority of cases in all age groups fell beyond the zero which is presently defined as *normal; i.e.*, most had some *hearing loss* according to present standards. Substantial percentages had average levels above 15 db which indicates the common occurrence of hearing defects in a population not exposed to industrial noise.

The chart of Figure 1 should prove useful to anyone who may wish to estimate on the basis of a single audiogram the likelihood that a change for the worse has occurred as the result of noisy employment or other cause. As an example of how this chart may be used, consider the hypothetical case of a man 25 years old who has an average hearing level of 15 db in each ear. From the Figure 1, it is seen that only 6% of the Wisconsin State Fair office workers in their twenties had hearing as bad or worse. Considering this group to be representative of the general population which is not exposed to hazardous industrial noise, one might expect to find hearing as bad or worse than in the hypothetical case in about one out of twenty unexposed men. Thus, a fairly rare condition exists, one which is not likely to be a chance occurrence, and further investigation is needed to determine whether it is causally related to employment. However, if the same hearing condition were found in a man 45 years old, it should not be regarded as unusual since the chart shows that 23% of the office workers in their forties had hearing levels of 15 db or greater. Accordingly, the probability would not be high that the condition is causally related to employment. Results of such comparisons are especially helpful

when correlated with history, medical findings and exposure evaluation.

Returning now to the new formula developed by the Subcommittee on Noise for estimation of impairment, it is interesting to see what binaural impairments are calculated for the Wisconsin office workers. Table I reveals that the incidence of binaural impairment according to this formula increased steadily with age from 14% in the 20–29 year age group to 62% in the 60–69 year age group. For those cases where impairment was found, the average amount tended to increase with age also. Thus, the use of a "low fence" of 15 db does not make adequate allowance for the deterioration of hearing with age in unexposed groups. Since the incidence and degree of impairment among these office workers was substantial, it is obvious that the use of the new formula is not particularly helpful in segregating cases of occupational hearing loss. The new formula merely assigns a number to the status of hearing which is all it was intended to do.

It is only by comparison of the hearing status of a suspected case of occupational hearing loss with hearing data on an unexposed group, such as that of Figure 1, that the significance of the hearing status may be determined. In making such a comparison, one according to his own conscience, mentally draws on Figure 1 a horizontal line representing a significance level below which impairment is possibly related to noise exposure and above which it is probably not. Thereafter, the significance of hearing status is indicated by noting, according to the age and average hearing level, into which of the two areas of the chart the case falls. In making judgments such a rule should be flexible since history, medical findings and exposure evaluation are quite important. But the approach is more helpful than the use of a low fence which can be represented as a vertical line on Figure 1 and which gives no information on the significance of the hearing status.

It should now be clear that definitions, terminology and formulas in use at the present to describe hearing normality and lack thereof need to be revised. Steps have already been taken in this direction but further improvements are needed. Results of the Wisconsin study of office workers provides information for comparing the hearing of a given case with that of the unexposed population in order to estimate the likelihood that a change for the worse has occurred.

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2. *Normal Hearing by Air and Bone Conduction*, Hearing Study Series, Bulletin 4, National Institutes of Health, U. S. Public Health Service, p. 3, 1938.
3. Davis, H., G. Hoople, and H. O. Parrack: The Medical Principles of Monitoring Audiometry. *AMA Arch. Ind. Health 17:* 1 (1958).
4. Guide for the Evaluation of Hearing Impairment. *J. Occ. Med. 1:* 167 (March, 1959).
5. *1954 Wisconsin State Fair Hearing Survey*, American Academy of Opthalmology and Otolaryngology, 1957.

Postgraduate Course

THE UNIVERSITY OF WISCONSIN will present a course on "Effects of Air Pollution and Environment on Health" at the Wisconsin Center Building, Madison, May 19–20, 1960. Dr. Seymour B. Crepea, Associate Professor of Medicine and Director of the Allergy Clinic at University Hospitals, is the course Director. The staff from the University of Wisconsin will be augmented by speakers from several other medical schools and the U. S. Public Health Service. The course will be a clinical discussion on various phases of air pollution, and their effect on health. Industrial pollution, air-borne infections, and problems of rural air pollution will be considered. Physicians, engineers, and faculty members of colleges of agriculture and medicine will be interested in this course.

Requests for information and registration should be sent to Dr. Robert C. Parkin, Coordinator of Graduate Medical Education, University of Wisconsin Medical School, 418 North Randall Avenue, Madison 6, Wisconsin.

Critique of Our Present Noise Control Engineering Efforts and Accomplishments*

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Bolt Beranek and Newman Inc., Cambridge, Massachusetts

Introduction

DURING the past few years I have been concerned with a number of noise control projects aimed directly at hearing conservation. In working on these problems I found that frequently a great deal of fruitless effort had been expended because some of the basic engineering principles were being disregarded or overlooked.

In this critique of the present engineering efforts and accomplishments I would like to give an overall picture of the noise control problem from an engineering standpoint. I will try to eliminate as many engineering details as possible and will attempt to give an orientation to the various facets of the problem which would be most useful to industrial hygienists and plant engineers—the field workers who must be able to recognize the existence of the problem, diagnose its nature, and estimate the extent to which present engineering techniques can provide a successful solution.

The engineering aspects of the noise control problem involve:

1. The determination of acceptable noise exposure criteria.
2. The monitoring of the hearing acuity of new and exposed personnel.
3. The evaluation of noise exposure.
4. The design of noise control measures.

Engineering Criteria

Noise control begins with the determination of acceptable exposure limits. Thus the first step is to deduce from the available criteria a set of engineering limits which can serve a "go, no-go" gage in evaluating the acceptability of a noise environment. Such a simplified gage will necessarily have limitations in accuracy but it should reflect the essence of the more complicated empirical relations in an easily applied form.

The effect of noise in producing individual hearing loss depends upon the noise level, the frequency spectrum of the noise, the length of exposure, and the age and physical condition of the individual exposed. Assuming a uniform cross-section of working population, noise criteria can be reduced to a set of engineering limits such as that shown in Figure 1.

Here it is assumed that the noise is broad band, and the curves represent the acceptable upper limits for noise levels measured in octave bands. The lowest curve represents the levels above which ear protection is recommended if an individual is exposed for about eight hours daily. The flat region at the higher frequencies approaches 85 db. Noise levels below this will result in negligible hearing loss beyond normal presbycusis for most persons exposed over a working lifetime of approximately 25 years. The second curve, 10 db higher, represents the limits at which ear protection is considered mandatory if the person is exposed for approximately eight hours daily. The next two curves represent levels for which ear protection is considered mandatory for exposures totaling respectively 10% and 1% of a normal working day. The top curve represents the upper limit considered safe for any single exposure, however short.

From these curves it is apparent that more low frequency noise can be tolerated than high frequency noise. Furthermore, there is a "trading" relation between time of exposure and the level which may be accepted. Thus a person who attends a machine only intermittently or a mechanic who experiences a jet operation only occasionally each day may accept much higher sound levels than someone in a machine shop who is exposed to a relatively continuous noise.

Instrumentation

It follows from the foregoing discussion that the simple measurement of overall noise level is not sufficient to evaluate noise exposure. Noise must be analyzed in at least octave bands and even smaller frequency intervals where pure tones are present. The times of exposure must be logged over a period of time sufficient to enable the determination of an average daily exposure. A good review of the available measuring instruments and techniques is given in the *Indus-*

* Presented at the Twentieth Annual Meeting of the American Industrial Hygiene Association, Chicago, Illinois, April 30, 1959.

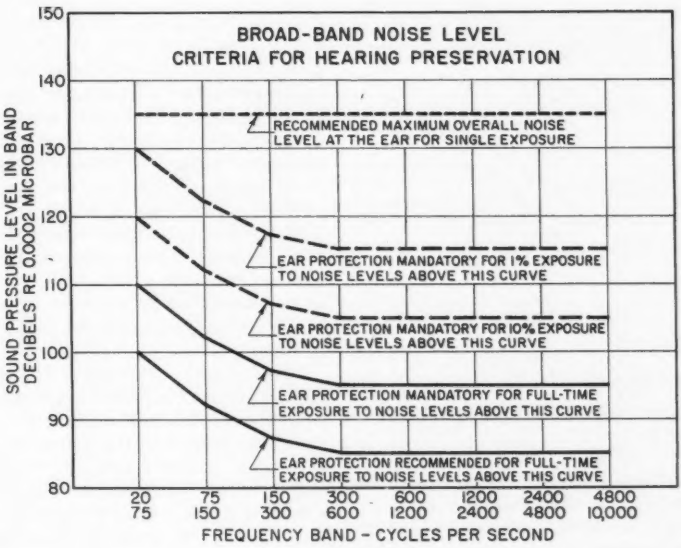
BROAD-BAND NOISE LEVEL
CRITERIA FOR HEARING PRESERVATION
SOUND PRESSURE LEVEL IN BAND
DECIBELS RE 0.0002 MICROBAR
150
140
130
120
110
100
90
80
RECOMMENDED MAXIMUM OVERALL NOISE
LEVEL AT THE EAR FOR SINGLE EXPOSURE
EAR PROTECTION MANDATORY FOR 1% EXPOSURE
TO NOISE LEVELS ABOVE THIS CURVE
EAR PROTECTION MANDATORY FOR 10% EXPOSURE
TO NOISE LEVELS ABOVE THIS CURVE
EAR PROTECTION MANDATORY FOR FULL-TIME
EXPOSURE TO NOISE LEVELS ABOVE THIS CURVE
EAR PROTECTION RECOMMENDED FOR FULL-TIME
EXPOSURE TO NOISE LEVELS ABOVE THIS CURVE
20 75 150 300 600 1200 2400 4800
75 150 300 600 1200 2400 4800 10,000
FREQUENCY BAND - CYCLES PER SECOND

FIGURE 1.

trial Noise Manual published by the American Industrial Hygiene Association in 1958.

Usually measurements of noise exposure involve two processes; first, noise levels are determined with a sound level meter and octave band analyzer at various typical locations in a noisy area; and then independent observations are made of the length of time personnel occupy these areas. This technique is simple and although somewhat tedious will continue to be widely used. More detailed measurements can be made using magnetic tape recordings which can be subsequently analyzed and averaged over a working day. These are particularly useful in situations where noise levels fluctuate over wide ranges in an unpredictable way.

New devices which attempt to integrate the noise exposure directly are under development. Eastman Kodak has developed a device called a a Continuous Time Distribution Noise Level Meter. The Navy has a so-called "Noise Cumulator" and the Research Center Sub-Committee on Noise at Los Angeles has a "Noise-time Cumulator." Other devices may be available shortly which can be worn by a worker in a noisy area and which will indicate total exposure and provide a warning against hazardous exposures.

The field of instrumentation also includes improvements in audiometric devices including a wide range of audiometers and several audiometric rooms for providing the necessary quiet test environments. These devices provide for the detailed examination of hearing acuity and also provide the means for making quick and frequent checks which indicate any change in hearing acuity. Such checks aid the early detection of any highly sensitive individuals before permanent hearing loss is produced.

Noise Control Techniques

In approaching the problem of noise control itself, it is important to consider the system as a whole. Frequently much effort is expended ineffectively by concentrating attention on a single part of the noise system where several, less noticeable parts may contribute significantly to the noise exposure problem. Any noise system may be thought of as consisting of three parts, source-path-receiver. The source may be any one or more pieces of machinery or associated equipment. The path may be the direct one through the air between the machine and its operator or may be any circuitous route involving the various parts of the machine itself, the material being fed to or from the machine, machine mounts, building structure, associated equipment, and finally the air between these items and the person in question. The receiver is a person, usually the machine operator, but frequently other persons also working in the vicinity of noisy equipment.

Many of the procedures and several excellent typical examples of noise control have been presented in the *AIHA Industrial Noise Manual.*

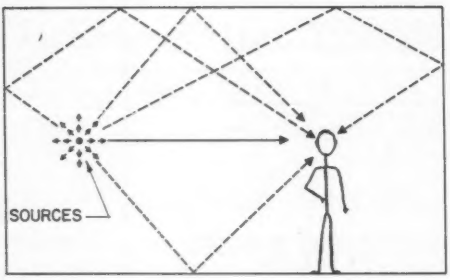

FIGURE 2. Schematic representation of a sound source in a room.

Numerous other examples can be found in *Noise Control* and in texts on the subjects.

The following discussion presents a general picture of the available noise control techniques and the limitations of their effectiveness in the situations for which they can be used. Noise control effort is invariably most effective when introduced before a factory or process is put into operation. Frequently the proper choice of machinery, its location, or the construction and treatment of its enclosure can reduce if not eliminate noise hazards. Such advanced planning can effect noise reduction at far less cost than that required for a remedial modification at a later time. However, the same acoustical principles are involved whether a building or a process is in the planning stage or is already in existence.

Consider first a simple sound source in a room as shown in Figure 2. Sound radiates in all directions and is reflected from the surrounding walls or other hard objects. A person in the room hears both the direct and reflected sounds. If he is close to the source, he hears primarily the direct sound and can locate the source distinctly with his ears. If he is farther away, he hears primarily reflected sound and in general cannot locate the source by listening.

The types of noise control measures which are effective depend upon the location of the receiver with respect to the source. If the person to be protected is close to the source, an enclosure for the source or even a partial enclosure or a baffle will be effective in reducing the direct sound by reflecting it away from the listener. In this position, however, the addition of acoustic absorption to the ceilings or walls will provide no relief at all since such material will reduce the reflected sound only, and this sound is already low in comparison to the direct sound. Conversely, when the person is far from the source, acoustic absorption spread around the room will be very effective. An enclosure for the noise source will also be effective if there is indeed one principle noise source; how-

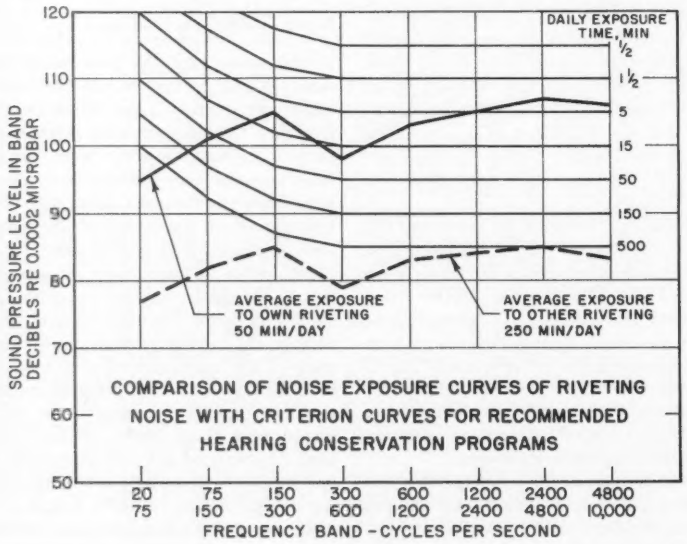

FIGURE 3.

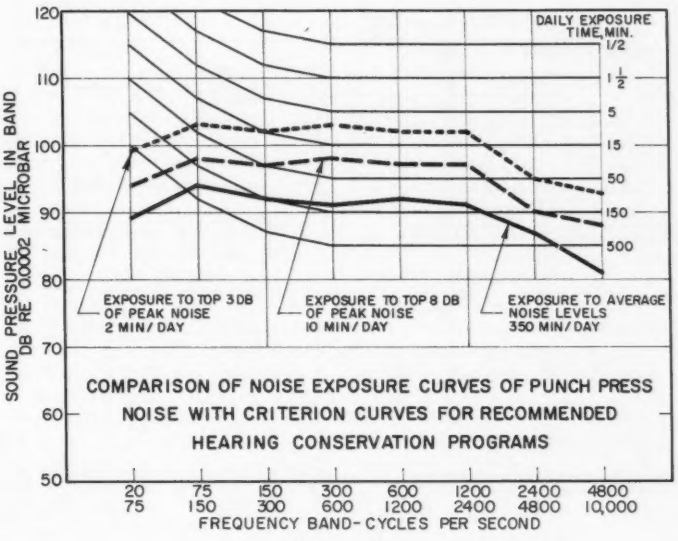

FIGURE 4.

ever, if there are several sources each must be enclosed to be effective. Partial enclosures or baffles between noise sources and the receiver are almost completely ineffective because most of the noise in the room travels around the baffle by reflecting from the walls and ceiling.

Generally, a satisfactory noise reduction solution will involve treatments to reduce both the direct and the reverberant sound. The system approach requires an evaluation of all causes for potential hearing damage for all persons involved, and the development of an overall program of exposure control. Such a program may include not only physical noise control measures but may also include some changes in work schedules and operator's positions. When viewing the overall system it is possible to see that some regions having relatively intense noise may be found acceptable if they are occupied only infrequently, while quieter regions which are used constantly may be found to require treatment.

As an engineering tool in the evaluation of exposure, the noise limits indicated in Figure 1 can be replotted as shown in Figure 3; here the limits for which ear protection is recommended are given for various exposure times, expressed in minutes per day. On such a graph, measured noise spectra can also be plotted for direct comparison. Two such spectra, measured in a riveting room are included in Figure 3. The upper spectrum was measured in the operator's position when his own riveting machine was operating.

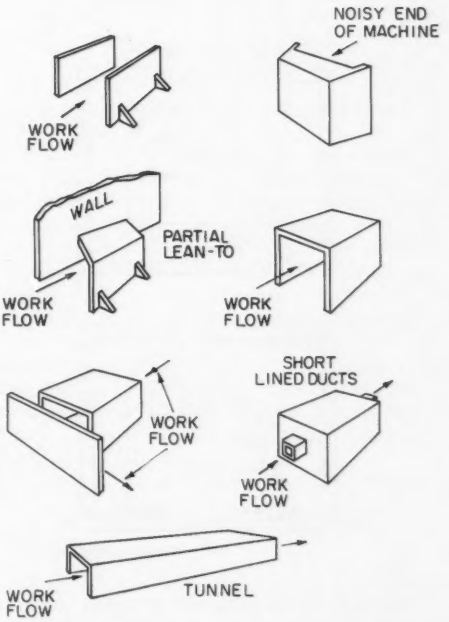

FIGURE 5. Typical enclosures and baffles for noisy machinery.

The lower spectrum is an average one measured at various positions which the operator might

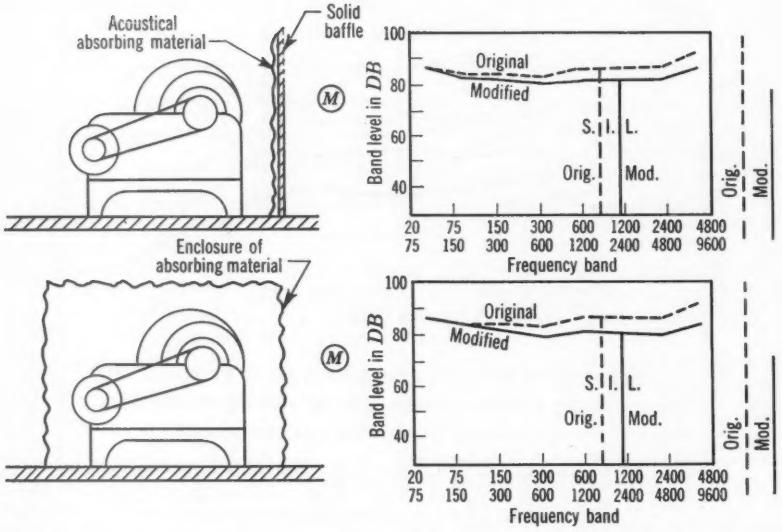

FIGURE 6. Noise reduction provided (a) by a rigid partial enclosure and (b) by a total enclosure of porous acoustical absorbing material.

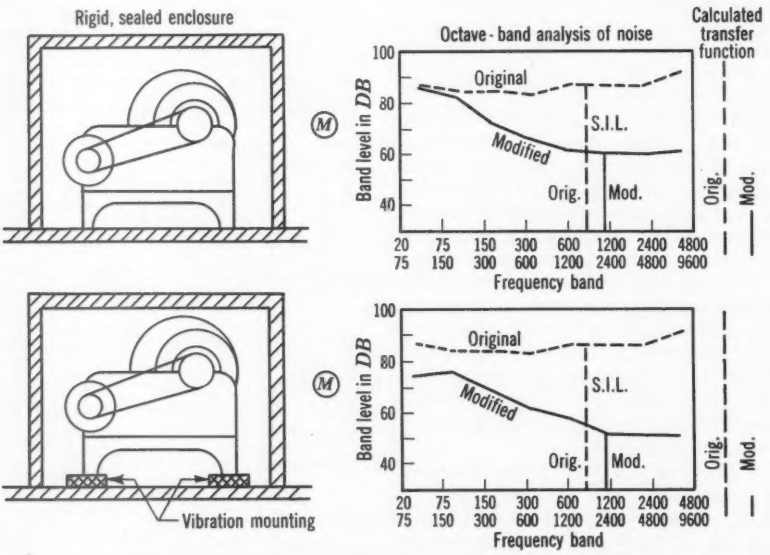

FIGURE 7. Noise reduction provided (a) by a rigid air tight enclosure and (b) by a similar enclosure and vibration mounts to reduce solid borne noise.

occupy when his machine was off. Applying to each of these an amount of time characteristic of the normal daily work schedule we find that the operator's exposure of 50 minutes per day to his own machine far exceeds the limit of approximately three minutes which would be acceptable for this noise level. The longer exposure of 250 minutes to the general background level is satis-

factory since this level would be acceptable even for a full time daily exposure.

From such a plot it is easily concluded that noise reduction should be applied directly to the riveting machine to protect the operator during the riveting operation, and that no general reduction of background levels are needed. The solution of such a problem might be a partial enclosure. Such an enclosure, which is more than a simple baffle will also decrease the general room noise levels.

A similar plot for a punch press operation shown in Figure 4 might be expected to yield similar results, but in this instance the noise peaks have a short duration. The total daily exposure time to levels within 3 db of peak value is only two minutes. The total time of exposure to noise within 8 db of the peak levels is only ten minutes. Neither of these exposures exceeds the acceptable limits. However, the general background level is approximately 5 db above the level for which an exposure of 350 minutes would be acceptable. In this case the addition of acoustic absorption to the room to reduce the background level would be effective but the installation of a baffle between a machine and an operator would be worthless. An acceptable solution might involve a deep ceiling treatment or the installation of unit sound absorbers in any available space distributed throughout the machine area.

Typical enclosures and baffles are illustrated in Figure 5. They may range from simple walls to full enclosures designed to fit a particular operation. The amount of noise reduction available varies greatly with the type of construction and the completeness of the enclosure. For a qualitative picture of the range of noise reduction available, Figures 6 and 7 illustrate some partial and full enclosures with octave band measurements showing the noise reduction to be expected.

Summary

Noise control for the conservation of hearing is still far from a closed book. The principles are well documented, but there are several regions in which—serious work is needed.

In particular, practically all of the engineering noise exposure limits are based upon the effects of long term exposure to relatively continuous broad band noise. There is need to determine the effects of other types of noise upon the hearing of exposed persons. Pure tones and impulsive noises are found in many industrial situations. The relative effects of short exposures to high level noises as compared to extended exposure lower level noise also needs further study.

The problem of measuring impulsive noise has not yet been solved satisfactorily. A punch press noise may have a maximum level as measured with the "fast" sound level meter only 3 to 5 db above the average "slow" reading but the true peak levels actually may be 8 to 12 db higher than this. When the true peak is measured, the width and the frequency content of an impulse is still elusive. New peak reading meters, both the General Radio and the H. H. Scott meters are gaining wide acceptance.

Even with new measuring devices which are becoming available, it will require much time to obtain meaningful results from case history studies and parallel studies on temporary hearing loss. More time will be required for standardization of measurements in order to obtain new engineering relations which may supplement the criteria now being used.

Engineering noise control should embrace cooperative effort between plant management, engineering, and medical services and should include advanced planning for noise control in all new processes and new construction. Noise control is such a complex engineering problem that in general it is not economically practical for each industrial plant to train or maintain an engineering staff to solve these problems. However, it should be the responsibility of the engineering and medical staff to be able to recognize the existence of noise hazards through suitable monitoring of working conditions and to advise management as to the need for corrective action.

Air Pollution Inventory Procedure and Results*

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Introduction

IN RECENT years several techniques for developing air pollution inventory data have been described and a considerable amount of source emission data based on test, usually specific to an operation or process, has been published. It remains then for the investigator charged with the responsibility of determining the amount and character of air pollutants in a given geographic area, to decide on methodology and collect and assemble data. Invariably, pollution emission levels are estimated, particularly for such multiple sources as transportation, and combustion of fuels and solid wastes. Utility companies, Boards of Commerce, shippers, newspapers, fuel institutes, the Bureau of Mines, fuel industry journals and fuel producers are sources of fuel use data and incineration quantities can often be furnished by local governmental sources. The final emission data for such sources is at best an estimate, the validity of which is dependent upon the reliability of the information assembled.

Industrial plants emit a wide variety of pollutants sometimes in enormous quantities and where many industries and a sizable geographical area are to be inventoried, the task can be time consuming, detailed and difficult. It is conceivable that each industrial emission source in an area will be studied and evaluated or as was done in the survey to be described, the industrial emission levels can be determined through sampling of a representative group of similar plants, by having large industries provide information on their specific processes, production rates and emission levels and finally, by direct evaluation of specific emission sources. The investigator finds it necessary to integrate different types of information obtained in the various ways mentioned.

The Technical Advisory Board of the International Joint Commission submitted a detailed report on air pollution in the Detroit-Windsor area. Much of the report, which is soon to be published, concerns shipping on the Detroit River. Chapter VI contains detailed information on air pollution levels attributable to other than marine sources, including contaminant emissions related to combustion processes, transportation and manufacturing. In 1956 the Michigan Department of Health, under contract to the United States Public Health Service, assisted in the gathering of a portion of the information presented, the result of a detailed air pollution survey of industry in certain portions of Wayne, Macomb and Oakland counties.

The overall study plan initiated by the U. S. Public Health Service included a similar air pollution study of industrial processing effluents within the city of Detroit and a group of engineers associated with Wayne State University conducted this portion of the study. Arrangements were made for effective cooperation between the Wayne State University group and the Michigan Department of Health survey team.

Since the Division of Occupational Health already had district offices located in Wayne County and in Oakland County, personnel from these offices were assigned to the task of gathering the air pollution data. While it was readily realized that a door-to-door study of every industrial establishment in the study area would be virtually impossible, it was planned to start the study on this basis in order to arrive at certain conclusions concerning a means of effectively surveying industrial areas. Although maps of the area, industrial plant tabulations and the Division of Occupational Health file data were used in planning the study it was soon found that much of the general information available was ambiguous and nonspecific. The plant information on file with the Division of Occupational Health was one of the most important sources of information inasmuch as practically all of the industrial establishments in the area had been surveyed at one time or another. Also the field personnel were familiar with plant location and the industrial processing being conducted. Utilizing all of the information available with regard to the location of industrial establishments and the products being manufactured, as well as information already obtained as a result of occupational health or air pollution studies in many of the plants concerned, a door-to-door study of those plants considered significant sources of air pollution was conducted.

Study Procedure

APPRAISAL THROUGH INDIVIDUAL PLANT VISITS

The survey was concerned with industrial process effluents and accordingly all types of manu-

* Presented at the Twentieth Annual Meeting of the American Industrial Hygiene Association, Chicago, Illinois, April 30, 1959.

facturing establishments were included with the exception of most domestic and commercial establishments and all transportation and power generation facilities. The study included industrial plants ranging from small asphalt plants and dry-cleaning shops to the greatest single source of air pollution in the area, the steel mills. These plants varied greatly in size, both in terms of the working population and production figures, ranging from the small shop employing one or two people and emitting pollution loads measured in terms of a fraction of a pound per day to the large industrial plant employing as many as 75,000 people and emitting pollution levels measured more appropriately in terms of tons per day.

SAMPLING OF CERTAIN SOURCE CATEGORIES

In surveying several industrial categories the procedure was based on a sampling of a representative number of plants rather than a survey of all of the plants in the area, thereby enabling a satisfactory weighting of air pollution from these sources. Those types of plants specifically included in the statistical sampling procedure were the dry cleaning shops, service garages and automobile bump shops, although original survey plans included concrete mixing plants, and fuel oil and gasoline storage depots as industries to be sampled. However, it was soon found that the concrete mixing plants and fuel storage plants would have to be visited individually inasmuch as pollution was based not only on the production or the amount of material handled but also upon the type of equipment being used, handling procedures and in the case of the gasoline and oil storage facilities, the specific type of tanks being used for storage.

DATA COLLECTED—GENERAL

Specific Information Requested. The survey team used a printed form for gathering necessary inventory data. In most cases the form was filled out as completely as possible at the time of the plant visit. Several of the large plants required additional time for completing the forms and sent the data through later. Usually the process or operation, the equipment used and the capacity of the equipment could be listed without too much difficulty. However, most plants were reluctant to give production data, and generally speaking only a limited amount of such information was made available to the survey team. We were interested in the raw or starting materials for the process and this information was made readily available. Contemplated process changes were a point of interest, particularly in the case of those industries where such process changes could result in reduction of the pollution load. The pollutants were described in the center section of the form and field personnel were asked to note whether it was gaseous or particulate, what its composition was and when directly available, the pollution load on an hourly and a daily basis. In most cases it was found necessary to calculate the pollution load based on both the information obtained and outside sources of information. In some instances the amount of material emanated to the outside was determined by first learning the amount of material collected, the type of collector used and then estimating the efficiency of the collection equipment. The field personnel collecting such data at the time of the plant visit usually entered as much information as possible and left the calculation of the pollution load and other calculations to the person responsible for assembling the data. It is interesting to note that generally speaking, plant management knew very little about the performance characteristics or design of the collection equipment they had available. On very few of the survey forms collected was there a notation that additional air cleaning equipment was on order or contemplated for the near future. On the question of industrial waste disposal methods, it was determined that most of the smaller manufacturers relied on a pick-up service whereas the larger manufacturers had incineration equipment available on the premises. Non-combustible rubbish was hauled to a dump by some form of pick-up service. In a few instances city service was available for the hauling away of rubbish. One item on the survey form, "Plans for Future Expansion or Re-Location", did not produce any significant results inasmuch as only a few manufacturers indicated that they were planning on future expansion or re-location.

Degree of Cooperation from Industry and Reliability of Information Obtained. Industry cooperated to the best of their ability considering that some of the questions asked required information they do not commonly make available. It was found that in the case of those plants not previously visited by members of the Division of Occupational Health, a considerable amount of explanation was necessary before any information could be obtained. The information obtained from the smaller plants was sometimes spotty and could lead one to believe that management was not always familiar with the various aspects of production techniques being conducted in the plant and more particularly with the air cleaning equipment available. In many cases information concerning amounts of raw or starting materials used and the capacity of equipment was unavailable because of actual lack of such knowledge. On the other hand the larger plants knew considerably more about their production equipment, the amount and type of air pollution taking place and

the collection equipment being utilized. However, when the latter were asked questions concerning type, make, size rated capacity or approximate efficiency of the unit, they were generally unable to offer specific information. It was usually necessary for the field personnel to obtain this information by checking the air cleaning equipment on the premises.

The smaller plants exhibited a definite lack of knowledge concerning their contribution to the general air pollution level, either through ignorance or a decided lack of interest. However, in the case of the plant (large or small), previously contacted by local authorities because of air pollution complaints, there was no lack of familiarity with the specific problem. They could be described as being air pollution conscious.

Pollution Estimation Procedures. In practically all of the smaller plants and many of the larger ones, management had no information whatsoever regarding the amount of pollution they were contributing to the outside atmosphere. It was therefore necessary for the survey team to obtain sufficient data which in some way could be used for determining pollution levels. As previously mentioned questions were asked regarding amounts of materials used, amounts evaporated, and amounts collected, if collection equipment was being used. Questions were also asked concerning rate production or the amount of material being handled, as in the case of a refinery or oil storage facility. Frequently, knowing the air volume handled by the exhaust system, the dimensions of a cyclone type collector or the volume of material collected was all that was needed to arrive at a reliable estimate of the amount of contaminant exhausted to the outside. Published information was frequently relied upon as a means of estimating pollution levels. For example, in several instances, production data was made available to the study team but little or no information could be supplied with regard to pollution levels. In the case of the open hearth furnace process for producing steel or the commonly used cupola in the grey iron foundry, it was possible to utilize previously published information and arrive at pollution level data on the basis of production figures which were obtainable. Many of the estimation procedures used are noted in Table VII.

Survey Results

INDUSTRIAL SOURCES OF POLLUTION

Table I lists a sample of the inventory of air pollutants in terms of industrial category, the specific process giving rise to the pollution, the composition of the pollutant, the type of pollutant (gas, particulate, fume or mist) and finally and most important the amount of material emitted to the atmosphere. The industrial categories tabulated are numbered in accordance with the code system used by the U. S. Bureau of Census (1957).

The grand total, 1,952,307 pounds of material emitted to the atmosphere per day as a result of industrial processing does not, as previously mentioned include products of combustion. Nevertheless, 976 tons of material per day represents a significant atmospheric loading. Further analysis of the data indicates that the steel mills in the area account for more than half of the total pollution load with automobile manufacturing, petroleum refining, inorganic chemical manufacture, gasoline and oil storage and handling, the manufacture of concrete and concrete products and the manufacture of asphalt all contributing lower but large amounts of contaminants to the atmosphere. The automobile industry contributes the second largest amount in terms of total loading and it should be mentioned that this figure of 254,487 pounds per day includes pollution attributable to the industry's steel production facilities. Similarly a factor which tends to exaggerate the inorganic chemical manufacturing category is a cement plant which is run as one of the operations of a large chemical manufacturer. The cement plant contributed 60,000 pounds of cement dust per day to the total pollution loading for the entire inorganic chemical category which is 71,041 pounds per day. It may be noted here that electrostatic precipitation collection equipment has since been installed at the cement plant resulting in a considerable reduction in the total amount of material emitted by the plant in question. Table II is a summary of the estimated pollution emissions in the entire study area as determined by the two study groups mentioned and indicates a total emission level of 1570 tons per day attributable to industry and commerce as compared to 976 tons per day in the study area adjacent to Detroit.

Table III lists the summation of pollution emissions based on industrial classification starting with the industrial group contributing the greatest amount of pollution and listing other industrial categories in order to decreasing pollution magnitude.

Table IV lists contaminant levels for the more common materials encountered as air pollutants. The total loading identified as iron oxide is perhaps exaggerated inasmuch as the iron oxide emanated from most of the processes listed was accompanied by lime, carbon, silicates and other materials. Crude oil listed as the second greatest pollutant was attributable mainly to oil refining

TABLE I

Sample of Tabulation System Used for Describing Amount of Pollution by Industrial Category

U. S. Census Code No.	Manufacturing or Product Description	Process	Composition	Type[1]	Amount (pounds per day)	Total (pounds per day)
281	Inorganic Chemicals	$FeCl_2$ $FeCl_3$ Mfg.	HCL	G	175	
		NH_3 Mfg.	NH_3	G	50	
		H_2SO_4 Mfg.	SO_2	G	4,310	
		Na_2CO_3 Mfg.	NH_3, H_2S	G	577	
			Na_2CO_3	P	1,920	
		Lime burning	CaO	P	800	
		Kreelon Mfg.	HCl, Cl_2	G	35	
		Iron melting	Iron oxide	F, P	500	
		Carbose Mfg.	Carboxy methyl cellulose	P	144	
		Cement Mfg.	Cement	P	60,000	
		Coal pulverizing	Coal	P	1,400	
		Chlorine Mfg.	Cl_2	G	91	
		Caustic Mfg.	SO_2	G	20	
		Ethylene glycol Mfg.	SO_2	G	219	
		Cupola flux Mfg.	Fluorospar	P	800	71,041
3312	Blast Furnaces & Steel Mills (Also see #371)	Electric furnace Melt.	Iron oxide[2]	P	34,956	
		Oxygen process	Iron oxide[2]	P	41	
		Scarfing	Iron oxide[2]	P	16,140	
		Bessemer	Carbon[2]	P	33,000	
		Open hearth	Iron oxide[2]	P	1,100,000	
		Sintering	Coke & iron oxide	P	6,200	
		Welding	Iron oxide	P	260	1,190,597
3321	Grey Iron Foundries	Melting in cupola	Iron oxide	P	1,955	
		Sand handling	Sand	P	4,416	
		Pouring & core baking	Acrolein[2]	G	2,628	
		Chipping & grinding	Iron & abrasive	P	34	
		Shot blast	Steel & sand	P	4	
		Sand blast	Sand	P	46	
		Galvanizing	ZnO, $ZnCl_2$	F	65	9,148

[1] G- Gas, P- Particulate, F- Fume

[2] Main constituent

TABLE II

Summary of Estimated Pollution Emissions in Study Area

Source	Emission in Tons per Day					
	Industry and Commerce			General Public		
	Solids	Gases	Total	Solids	Gases	Total
Coal (combustion)	190	730	920	210	580	790
Blast Furnaces and Steel Mills	640	—	640			
Petroleum Fuels (combustion)	0	490	490	0	260	260
Misc. Industrial & Commercial	90	190	280			
Petroleum Refining	—	160	160			
Iron and Steel Foundries	110	60	170			
Motor Vehicles (gasoline)	0	110	110	0	740	740
Solvent Usage	0	140	140	0	50	50
Refuse Burning	10	40	50	20	160	180
Natural Gas (combustion)	—	40	40	0	80	80
Gasoline Handling Losses	0	20	20	0	130	130
Total			3,020			2,230

Emission Level (excluding fuel combustion) in Total Study Area—Industry and Commerce 1,570 T/D

Emission Level (excluding fuel combustion) in Michigan Department of Health Study Area— Industry and Commerce 976 T/D

operations where the crude was lost due to evaporation. Thinner or solvents listed as the third greatest contaminant is actually made up of all of the solvent materials used in spray painting and for other typical solvent applications and is comprised essentially of the naphthas, isopropyl alcohol, toluene, xylene, amyl acetate, butyl acetate and a similar range of materials. Cement dust listed fourth is attributable to losses in handling in those plants where concrete is batch mixed.

TABLE III
Summation of Pollution Levels (Pounds per Day) Based on Industrial Classification

U.S. Census Code Number	Manufacturing or Product Description	Pollution Level (pounds per day)
3312	Blast Furances & Steel Mills	1,190,597
371	Motor Vehicles & Equipment	254,487
2911	Petroleum Refining	239,850
281	Industrial Inorganic Chemicals	71,041
5092	Gasoline & Oil Storage	64,473
3271	Concrete Products	27,375
2951	Paving Mixtures & Blocks	24,414
39	Misc. Manufacturing	10,552
3295	Misc. Non-Metallic Mineral Products	9,842
7216	Dry Cleaning	9,650
3321	Grey Iron Furnaces	9,148
252	Furniture & Fixtures	5,112
39	Plastic Fabricators	3,735
336	Non-Ferrous Foundries	3,508
344	Structural Metal Products	3,488
354	Metalworking Machinery	2,814
354	Special Industrial Machinery	2,808
3461	Metal Stampings & Coating	2,793
4953	Solid Waste Disposal	2,066
349	Misc. Fabricated Metal Products	2,033
3341	Secondary Non-Ferrous Metals	1,841
3323	Steel Foundries	1,776
2842	Cleaning & Polishing Preparations	1,040
3471	Plating & Polishing	1,020
362	Electrical Industrial Apparatus	1,017
3531	Construction & Mining Equipment	802
2818	Organic Chemicals	800
3479	Enameling & Lacquering	764
2851	Paints & Varnishes	651
3471	Buffing & Polishing Shops	571
2821	Plastic Materials	474
3791	Motor Vehicle Repair	446
3471	Sand Blasting Job Shops	375
3399	Heat Treating Shops	212
372	Aircraft and Parts	161
3069	Rubber Industries	157
2431	Millwork & Related Products	141
3275	Gypsum Products	90
339	Misc. Primary Metal Industries	45
3479	Galvanizing	44
373	Ships & Boats	21
3591	Machine Shops	14
3011	Tires & Inner Tubes	13
2653	Misc. Paper Goods	11
2899	Chemicals & Allied Products	10
7621	Service & Household Machines	7
3391	Iron & Steel Forgings	7
3251	Stone, Clay & Glass Products	7
3799	Transportation Equipment	2
249	Misc. Wood Products	1
3591	Welding Job Shops	1
	Total	1,952,307

TABLE IV
Contaminant Levels for the More Common Materials (Pounds per Day)

Contaminant	Total Loading (pounds per day)
Iron oxide	1,281,888
Crude oil	220,050
Thinner	78,879
Cement	70,382
Gasoline	64,896
Core gas	64,747
Carbon	33,000
Sand	21,466
Clay	17,050
Light hydrocarbons	11,400
Trichlor	10,634
Oil fumes	6,255
Sulphur dioxide	4,312
Abrasive material	3,299
Naphtha	3,229
Copper oxide	2,903
Sodium carbonate	2,031
Wood	1,992
Zinc oxide	1,834
Coal	1,400
Inorganic acid	948
Lime	800
Perchlor	670
Organic acid	474
Lead oxide	433

Notes: 1. Iron oxide as tablulated is essentially main constituent of mixture which may include materials such as silicates, lime, carbon.
2. Materials such as thinners, iso-propyl alcohol toluene have been grouped under heading of thinners.

The relationship of production rate and pollution emission level is noted in Table V which relates these for a few industrial categories. Table VI lists additional data on emissions from the steel mills in the study area.

As previously explained, it was found necessary to estimate the emission levels from certain sources. Table VII lists some of the information used for estimation purposes.

Conclusions

1. The study technique utilized was essentially a door-to-door canvassing of industrial establishments and produced good results. There is no question but that a similar study procedure can be adapted to any geographical area but it is suggested that before this is done consideration be given to several important factors related to this study. The study team was comprised of experienced personnel who normally do occupational health work in the area surveyed. They

TABLE V
Production and Pollution Data for Selected Industrial Categories

U.S. Census Code No.	Manufacturing or Product Description	Product	Production Rate pounds per day	Pollution Level—Total in pounds/day
281	Inorganic Chemicals	Chlorine	980,000	
		Ammonia	140,000	
		H_2SO_4	600,000	
		Cupola flux	20,000	71,041
2821	Synthetic Resins	Phthalic anhydride	60,000	
		Synthetic resins	300,000	474
2818	Organic Chemicals	Rubber chemicals	400,000	
		Alcohols & ester	1,000,000	
		Amyl naphthalene	60,000	
		Thioureas	60,000	
		Aliphatic amines	400,000	
		Thioalcohols	20,000	800
2911	Petroleum	Oil refined	14,670,000	239,850
2951	Paving Mixtures & Blocks	Asphalt	6,130,000	24,414
3271	Concrete Products	Concrete mix	17,629,430	27,375
3295	Misc. Non-Metallic Mineral Products	SiO_2 (Sand)	200,000	9,842
3312	Blast Furnaces & Steel Mills (Also see #371)	Pig iron	3,000,000	
		Steel (Bessemer)	6,666,000	
		Steel (electric)	3,348,000	
		Steel (open hearth)	27,200,000	
		Oxygen process	3,000, 00	
		Sintering	7,222,000	1,190,597
3321	Grey Iron Foundries	Iron castings	289,760	9,148
3323	Steel Foundries	Steel castings	728,000	1,776
3341	Secondary Non-Ferrous Metals	Zinc	106,000	
		Lead	12,270	1,841
336	Non-Ferrous Foundries	Brass	190,000	
		Aluminum	3,273	
		Zinc	11,820	
		Copper	2,670	3,508
371	Motor Vehicles & Equip.	Motor vehicles per year	427,510	254,487
5092	Gasoline & Oil Storage	Gasoline	15,292,200	
		Oil	5,732,250	64,473

TABLE VI
Additional Data on Specific Air Pollution Sources

Process Description	Steel Mills			
	Production (tons per day)	Pollution Level (tons per day)	Percent Production-Covered by Air Cleaning Equip. (%)	Type of Air Cleaning Equip. Used
Open hearth furnaces	13,600	582.0	0	None
Bessemer converters	3,333	16.5	0	None
Electric arc furnaces	1,674	17.5	37	High efficiency Wet scrubbing[1]
Oxygen process	1,500	Negligible	100	High efficiency Wet scrubbing
Sintering	3,611	13.1	100	Dry cyclone[2]
Scarfing	—	8.0	11	Wet centrifugal[3]

(1) Combination of cooling chamber, gas washer, Thiessen Disintegrator and moisture eliminator. Electric furnace effluent 0.020 grains per cubic foot (60°F) and oxygen process effluent 0.0042 grains per cubic foot. Total volume of gas handled is 107,700 cfm at 60°F.

(2) Low efficiency type. Total volume of gas handled is 260,000 cfm. Pollution level based on estimated loading of 2 grains per cubic foot and collection efficiency of 75%.

(3) Wet centrifugal, about 80% efficient, handling 100,000 cfm.

were engineers familiar with the industries they visited and were essentially men who knew what they were after but who were necessarily limited in the thoroughness of their job by the time factor. Much of the information obtained was made available as a result of previously established working channels, this again being the result of industrial hygiene activity in the area. A satisfactory estimate of emission levels on the basis of fuel consumption or rated production cannot be validated without knowledge of the processes and air cleaning equipment used. Therefore, personal visits are necessary in such a study.

2. The data form used was basically satisfactory. In many cases supplemental data was added and with large plants the supplemental data was extensive. Experience with the tabulation of industrial processing data acquired during and since the survey indicates the advisability of utilizing a punch card system for such surveys.

3. Air cleaning equipment was found in use in many of the industrial plants studied. The use of air cleaning equipment does not always reflect an air pollution consciousness on the part of management. In some instances, such equipment was sold as an integral part of the production equipment, a good example of this being the bag-type collector that almost invariably was found in

TABLE VII
Estimation of Pollution Levels from Various Operations

Process	Contaminant	Pollution Load Associated with Process	Source of Information
Automobile burning (dump)	Carbonaceous matter	250 lbs. per automobile	Not based on study data
Concrete batching	Cement	0.25–1% of cement used, depending on handling	Survey of 12 plants
Core baking	Acrolein[1]	6 lb. core gas per gal of core oil used	Core oil and core gas evaluation, Hiram Brown, *American Foundryman 18:* 52 (Aug. 1950).
Degreasing	Trichlorethylene Perchlorethylene	95–100% of amount used lost by evaporation	Correspondence: E. I. duPont de Nemours and Co. Detroit, Michigan
Dry cleaning	Perchlorethylene	86.5 gal per plant per month average (1 washer, 4–8 hrs per day operation)	Survey of 36 plants
Dry cleaning	Stoddard solvent (petroleum distillate)	384 gal per plant per month average (1 washer 8 hrs per day operation)	Survey of 23 plants
Electric arc welding	Iron oxide[1]	1–2% of weight of electrode	Correspondence: The Lincoln Electric Company, Cleveland, Ohio
Electroplating and metal cleaning	various	Based on rate of gassing and make-up solution required Gassing rate — Loss (% of make-up) High — 5% Medium — 3% Low — 2% Nil — 0	Gassing rate data listed in: *Electroplating Engineering Handbook*, Edited by A. K. Graham, Reinhold Publishing Corp. New York (Tables 6, 7 and 8), p. 519–523.
Iron melting (cupola)	Iron oxide[1]	20 lbs. per ton of grey iron produced (average value)	*A Study of Cupola Design and Operating Factors that Influence the Emission Rates from Foundry Cupolas*, R. C. Ortgies American Air Filter Co., Louisville, Kentucky *Control of Metallurgical and Mineral Dusts and Fumes in Los Angeles County, California*, G. L. Allen, F. H. Viets and L. C. McCabe, Bureau of Mines Circular 7627.
Lead melting	Lead oxide	1.5% of charge	Dust and Fume Standards, Louis C. McCabe, A. H. Rose, W. J. Hamming & F. H. Viets *Industrial and Engineering Chemistry 41:* 2388 (November 1949).
Brass melting	Copper oxide & zinc oxide	1.5% of charge	
Magnesium melting	Magnesium oxide	5% of charge	Survey data (1 plant)
Oil quench	Oil fumes	10% of make-up oil	Not based on study data
Painting	Thinners	60% of paint volume used	Value calculated on basis of composition of paints used in study area.
Soldering	Varies	0.5% of weight of solder used	Not based on study data
Steel-Bessemer converter	Carbon & iron oxide	0.5% of steel produced	Not based on study data[2]
Steel-electric arc	Iron oxide[1]	33 lb. per ton of steel produced	Test data at plant in survey area
Steel-open hearth	Iron oxide[1]	0.7 grains per SCFM and 930 cfm per 1000 lb. per hr process weight	*Control of Metallurgical and Mineral Dusts and Fumes in Los Angeles County, California*, G. L. Allen, F. H. Viets and L. C. McCabe, Bureau of Mines Circular 7627.
Steel-scarfing	Iron oxide[1]	29 lbs. per ton of steel (oxy-acetylene scarfing)	Test data at plant in survey area

[1] Main constituent.
[2] Probably low, conversion process reduces carbon content from about 3.5% (pig iron) to 1% or less.

operation in conjunction with a shot blast or sand blast unit. Just about every woodworking plant visited used a cyclone for collecting sawdust. Wet scrubbing equipment was commonly used in the chemical plants where just about every type of collector was found in use.

4. The need for more and better air cleaning equipment becomes obvious as one reviews the various industrial categories of processes and the pollution levels determined. A notable example is the steel industry. One steel manufacturer in the study area has successfully reduced the pollu-

tion level emanated from the plant to a negligible amount with the use of air cleaning equipment as compared to the competing industries in the same area which account for more than half of the total pollution level determined from all sources. On the other hand there are certain industries where the increased use of air cleaning equipment is not necessarily the answer. The handling and storage of fuel oil and gasoline and oil refining techniques are typical of industries which can effect considerable reductions in pollution levels emanated by modifying existing processes or using improved storage and handling equipment.

5. It is estimated that the application of control equipment of the proper type to the various industries studied would result in at least a 75% reduction in the total contaminant level for the area.

6. The larger manufacturing plants were cognizant of the air pollution problem and appeared to be on the brink of applying air cleaning equipment or effecting process changes in order to reduce their pollution levels. Many of these plants are located in areas where much pressure has been exerted by neighboring industries, citizens and governmental officials. Possibly with the enactment of state-wide legislation these plants can be encouraged to install the necessary control equipment, equipment which they are familiar with and which will result in an appreciable reduction in the pollution level attributed to industrial processing. One large steel producer has drawn up plans for the control of electric furnace fumes and even tested electrostatic precipitator type air cleaning equipment. Such interest in control equipment was evidenced for several years but can now be best described as latent. Another large steel producer, cognizant of the air pollution problem has effected a substantial increase in open hearth furnace capacity with little apparent attention to air cleaning problems.

7. It is difficult to generalize on the smaller manufacturing plant in terms of their attitude toward air pollution control. Some of the smaller manufacturing plants are cognizant of air pollution problems by virtue of neighborhood complaints whereas others are cognizant of air pollution in general but are totally disinterested in the installation of any control equipment. It appears that for some small plants as with some large ones, legislation is the only logical answer.

8. A recent spot check of several plants indicates that in the period since the survey was completed, emission levels have increased in the survey area.

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The Pre-Operational Environmental Survey for the Enrico Fermi Reactor—1958*

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Introduction

THE general aims and methods of a pre-operation radiological survey have been outlined previously by one of the authors.[1] The present paper summarizes the methods and the results of the first year of such a survey carried out in the environment of the Enrico Fermi Reactor. The survey is being conducted for the Power Reactor Development Company by the National Sanitation Foundation (NSF). Sample collection began in the spring of 1958 and the pre-operational phase is to continue until the reactor begins operation in 1960. The pre-operational data will provide a basis for comparison with levels of environmental radioactivity observed after the reactor is in operation.

Sample Collection

The locations where samples are collected are shown in Figure 1. The frequency at which each type of sample is collected at each location is shown in Table I.

Surface Water. One surface water sample per week is collected at each of the six locations shown in Table I. The sample consists of two gallons collected in a polyethylene jug. Single "grab" samples are taken at the Reactor Lagoon and at Swan Creek by immersing the jug in the water to be sampled. At Monroe, Grosse Ile, and Ann Arbor, small volumes of the raw water intakes are put into the 2-gallon jugs daily. The Toledo sample is a weekly composite of hourly samples taken from the raw water intake.

Underground Water. Samples of water from beneath the Reactor foundation are drawn at weekly intervals from a well drilled for this purpose. Before the sample is taken, about 50 gallons of water is pumped out to clear the casing. Samples of underground water from the nearest inhabited areas west and south of the Reactor Site are taken at monthly intervals from wells that supply the needs of two or three people. All underground water samples have a volume of two gallons and are collected in polyethylene jugs.

Rain. Precipitation is collected continuously at the six locations listed in Table I. At each of the four U. S. Weather Bureau Stations (Monroe Water Treatment Plant, Toledo Airport, Willow Run Airport and Sandusky Post Office), rain is collected in a standard gauge eight inches in diameter. Every six hours, when observable precipitation occurs, the gauge is emptied into a measuring device to determine the amount of precipitation. After this determination has been completed the rain water is poured into a 2-gallon polyethylene jug provided by the NSF. The jugs are picked up at monthly intervals.

Rain water samples at the other two locations are collected in a manner essentially that just described. The rain gauge at the U. S. Naval Station on Grosse Ile is five inches in diameter, and the collecting device at the Reactor Site is an 8-inch polyethylene funnel set in a 2-gallon polyethylene jug, instead of a standard gauge.

Note that while some dry fallout is washed into the collected sample by natural precipitation, no effort is made to collect this material during prolonged dry periods by rinsing down the gauges.

Dust. Airborne dust samples are collected at weekly intervals when possible at each of the four locations listed in Table I. Air is drawn continuously at a rate of approximately one CFM by a motor-driven Gast pump through a Gelman membrane filter two inches in diameter. Filters are changed weekly by NSF employees on the same schedule as that for water samples.

There has been some difficulty in obtaining continuous dust samples over a 7-day period. The membrane filters have occasionally ruptured, apparently as the result of large thermal changes, and leaks in the plumbing between the filter and the pump have developed from vibration. With the benefits of experience and minor modifications, the units are giving more reliable service.

Biota. Various biological media have been selected with a view to detecting biological concentrations of radioactive materials and to observing any significant quantities of these materials in the human food chain. No milk samples were analyzed in 1958, but consideration of the Windscale

* This paper was presented in brief form at the AIHA annual meeting at Chicago on April 30, 1959. The results of this Survey will appear in greater detail in a National Sanitation Foundation report to the Power Reactor Development Company.

incident has led to the inclusion of milk in the 1959 sampling program.

Samples of aquatic biota are collected six times a year at each of the twelve locations listed in Table I. Sedimentary material from lake and stream bottoms and the benthic organisms living in this material are scooped up with a Petterson dredge operated from a small boat. Higher aquatic plants, fish and plankton are gathered in nets handled from the boat. In most cases suitable samples of fish and sedimentary material can be acquired readily. Suitable quantities of aquatic plants frequently cannot be obtained at the four Lake Erie locations, but can usually be obtained at the eight inland locations. Plankton and benthos are commonly present in the collected material, but frequently not in sufficient quantities for the desired analyses. Since these two media are of particular interest, as possible concentrating agents and as primary nutrients in many food chains, samples substantially smaller than the desired minimum quantity are analyzed for gross β activity.

FIGURE 1. Map of the sampling locations in the region of the Enrico Fermi Rector.

Samples of terrestrial biota are collected six times a year at each of the eight locations listed in Table I. Within the desired area, sampling locations were selected, when possible, where apple trees and juniper bushes occurred near an open field inhabited by microtus, an herbivorous field mouse.

Apples are collected during their growing season from May through September only at Monroe, Ann Arbor, Sandusky and Harrow. Cabbages are collected during the same growing season at all eight locations. Only the edible portions of apples and cabbages are analyzed. Samples of juniper and grass are collected at all eight locations and from new growth when possible.

Microti are trapped with lethal, museum-type snap traps. Sometimes, even when there is evidence of their presence, repeated trappings fail to yield microti. On such occasions an attempt is made to press a nearby rabbit into service.

TABLE I
Sampling Media, Location and Frequency (number of samples per year)

	Reactor Site	Monroe	Lake Erie (Pt. aux Peaux)	Carleton	Swan Creek	Nearby Wells (2)	Grosse Ile	Toledo	Harrow, Ontario	Lake Erie (Colchester)	Huron River (Flat Rock)	Ford Lake (Belleville)	Lake Erie (Bono)	Ann Arbor	Sandusky	Lake Erie (Pelee Island)	Pond (Port Clinton)	Wolverine Lake (Brighton)	Totals
Apples	—	4	—	—	—	—	—	—	4	—	—	—	—	4	4	—	—	—	16
Benthos	6	—	6	—	6	—	—	—	—	6	6	—	6	—	—	6	6	—	48
Cabbage	4	4	—	4	—	—	4	4	4	—	—	—	—	4	4	—	—	—	32
Dust	52	52	—	—	—	—	52	—	—	—	—	—	—	52	—	—	—	—	208
Earth	6	6	—	6	—	—	6	6	6	—	—	—	—	6	6	—	—	—	48
Fish	6	—	6	—	6	—	—	—	—	6	6	6	6	—	—	6	6	6	60
Grass	6	6	—	6	—	—	6	6	6	—	—	—	—	6	6	—	—	—	48
Aquatic plants	6	—	—	—	6	—	—	—	—	—	6	6	—	—	—	—	6	6	36
Juniper	6	6	—	6	—	—	6	6	6	—	—	—	—	6	6	—	—	—	48
Mammals	6	6	—	6	—	—	6	6	6	—	—	—	—	6	6	—	—	—	48
Plankton	6	—	6	—	6	—	—	—	—	6	6	6	6	—	—	6	6	6	60
Rain	12	12	—	—	—	—	12	12	12	—	—	—	—	12	12	—	—	—	72
Sediment	6	—	6	—	—	—	—	—	—	6	6	6	6	—	—	6	6	6	54
Ground water	52	—	—	—	—	24	—	—	—	—	—	—	—	—	—	—	—	—	76
Water	52	52	—	—	52	—	52	52	—	—	—	—	—	52	—	—	—	—	312
Totals	226	148	24	28	76	24	144	92	32	24	30	24	24	148	44	24	30	24	1166

Sample Preparation

All samples are brought to the laboratory for analysis. Aliquots are taken and prepared for gross β counting. Aliquot size is determined by the required detection limits and by the sensitivity limits of the counters, as described in the next section. Preparation for gross β counting consists primarily of volume reduction by evaporation, ashing, or leaching, whichever is appropriate. This preparation involves no specific chemical separation. Following volume reduction, the samples are transferred to stainless steel planchets, dried and counted.

Leaching. Earth and surface sediment samples are dried overnight at approximately 90°C. An 8 gm aliquot of the dried sample is placed in a tared, numbered centrifuge tube. The aliquot is leached successively with water, ammonium acetate, a mixture of hydrochloric and oxalic acids, and nitric acids, as follows:

(1) 20 ml of the leaching solution is added to the tube containing the 8 gm aliquot.
(2) The tube is placed in a boiling water bath and the contents are stirred with a magnetic stirrer for five minutes.
(3) The tube is removed from the bath and centrifuged for 15 minutes at 4000 rpm.
(4) The supernatant liquid is decanted into a numbered beaker reserved for that particular sample.

These four steps are carried out twice with water and then twice with each of the three other leaching solutions in sequence. All eight volumes of supernatant liquid from a given sample are decanted into the same beaker. The contents of the beaker are evaporated to dryness on a hot plate. The dry residue in the beaker is taken up with 1.0 *N* nitric acid, transferred to a stainless steel planchet, dried and counted.

Evaporation. Rain, surface and ground water samples are reduced by evaporation. A 3-liter portion is withdrawn from each 2-gallon sample of surface and ground water after it has been thoroughly mixed. A 100 ml aliquot of the 3-liter portion is set aside for iodine analysis. The remaining 2,900 ml is evaporated to dryness on a hot plate. The dried residue is transferred to a planchet with 1.0 *N* nitric acid, dried and counted.

The total volume of the rain sample is measured and adjusted to one liter by evaporation or the addition of distilled water. A 100 ml portion is taken for iodine analysis, and an additional 500 ml portion is set aside for specific radioisotope analysis. The remaining 400 ml is passed through a millipore filter. The millipore filter is placed on a planchet, dried and counted. The filtrate is evaporated to dryness in a beaker on a hot plate. The dried residue is transferred to another planchet with 1.0 *N* nitric acid, dried and counted.

Ashing. All biological samples are reduced by dry ashing. Fish, rabbit and microtus samples occasionally exceed the size desired for gross β counting. In these cases, special preparation is necessary to obtain a representative aliquot. Such samples are weighed, homogenized in a Waring blender and placed in a 100°C drying oven. The dry, unattractive residue is weighed and the ratio of dry-to-wet weight is determined. A portion of the residue corresponding to approximately 10 gm of the wet sample is placed in a crucible, weighed and ashed in a muffle furnace. The ash is cooled, transferred to a tared planchet with 1.0 *N* nitric acid, dried and counted.

Filtering. Samples of airborne dust are collected on membrane fiters two inches in diameter. The filter is simply placed in a planchet and counted.

Radiochemical Procedures

The radiochemical procedures used here have been drawn from many sources;[2-10] they have been combined and modified by use and the exigencies of the survey to the point where it is difficult to attribute many parts of the procedures to the correct source. Where possible, the appropriate reference is indicated.

Pretreatment. The pretreatment of samples for radiochemical analysis is similar to the preparation of samples for gross β analysis.

An 8 gm aliquot of earth and surface sediment samples is leached for barium, strontium and the rare earths by carrying out the four steps described in the section on Sample Preparation twice with dilute nitric acid.[5] The leachate is analyzed for strontium and barium as described below. The leached aliquot is discarded.

A suitable carrier for the element to be isolated is added to the water samples which are then reduced to a manageable volume by evaporation. The reduced water sample is passed through a millipore filter to remove the insoluble material, presumably silica. The filter is dried, counted and stored. The insoluble material on the filter has always been found to contain less than 10% of the gross β activity and since the strontium contribution to this activity is relatively small,[10] it is ignored in the radiochemical analyses. The filtrate is used in the analyses described below.

Biological samples are ashed in a 550°C muffle furnace until only a fine, white ash remains. The ash is cooled and a mixture of dilute nitric and hydrochloric acid is added. A suitable carrier for the element to be isolated is added and the mixture is placed on a hot plate for half an hour to

permit exchange with the carrier to reach equilibrium. The dissolved material is freed from insoluble material by filtration. The filter is dried, counted and stored, and the filtrate is used in the analyses described below.

Ash of grass and juniper dissolve readily in this treatment, but the ash of higher aquatic plants is largely insoluble. The insoluble residue, after equilibrating with the carrier, retains less than 10% of the gross β activity, and as in the case of water, is ignored in the radiochemical analysis.

Barium and Strontium. Barium and strontium are precipitated first as carbonates. Calcium is then removed by successive treatments with fuming nitric acid.[10] Cations other than barium and strontium are scavenged by ferric hydroxide and filtered off. Barium is precipitated as the chromate, filtered, dried, weighed and counted. Strontium is precipitated from the filtrate as the oxalate, filtered, dried, weighed and counted.

Cesium. Silico-tungstanic acid is added to pretreated samples to which cesium has been added as a carrier. The cesium precipitates and is centrifuged, dried and counted.[5]

Iodine. Combined iodine in the pretreated sample is converted to free iodine with chlorine water and is extracted, together with any free iodine initially present, by carbon tetrachloride. Free iodine is removed from the carbon tetrachloride phase by shaking with an aqueous solution of sodium bisulfite, and subsequently precipitated as the silver iodide. The precipitate is filtered, dried and counted.

Potassium. Potassium is precipitated from the pretreated sample by sodium tetraphenyl boron, filtered, dried, weighed and counted.

Measurement of Radioactivity

Instrumentation. The total β particle disintegration rate in each sample is estimated by counting the planchet representing the sample in one of two gas-flow counters. The first counter, used for all determinations prior to December 15, 1958, is a windowless proportional counter, Nuclear Measurements Corp. Model PCC-11. It has a background of approximately 30 counts per minute and a net efficiency of 70% for β emitters with maximum energies above 0.76 Mev in a stainless steel planchet. Because the samples are placed within the counting volume, this device is sensitive to exudations from the sample. The widely varying chemical and physical nature of the samples has limited the usefulness of the PCC-11 for this survey.

The second counter, used for all determinations subsequent to December 15, 1958, is an end-window, gas-flow geiger counter with an anti-coincidence umbrella of 11 geiger counters, Tracerlab Model CE-14. It has a background of approximately one count per minute and a net efficiency of 40% for β emitters with maximum energies above 0.76 Mev in a stainless steel planchet.

Sample Size. The Power Reactor Development Company has stated its intent to limit release of radioactivity to such an extent that average concentrations in the environment will not exceed about 1% of those given in Table 3 of *National Bureau of Standards Handbook 52*. Of the β emitting materials which might escape from a reactor plant, the most restrictive limits are those of strontium-90: 1.3×10^{-12} and 5×10^{-9} μc/ml in air and water, respectively.

The Survey detection limits must be somewhat less than the stated operating limits in order to detect rising concentrations before operating limits are exceeded. For this Survey the minimum detectable concentrations in air and water have been taken as 1.3×10^{-13} and 5×10^{-10} μc/ml, respectively.

The minimum sample sizes consistent with these minimum detectable concentrations are simply those which provide the minimum activity detectable in a reasonable counting period (50 minutes) with each counter: 1.0×10^{-6} μc for the PCC-11, and 3.2×10^{-7} μc for the CE-14. The minimum sample sizes with the PC-11 counter are 7.7×10^{6} ml of air, 2,000 ml of water and 2,000 gm of biota. With the CE-14 counter the minimum sample sizes are 2.5×10^{6} ml of air, 640 ml of water and 640 gm of biota.

In general, the preparation of 640 gm of biological material for counting requires chemical separation. Biological samples of 50 gm are sought for routine collection and analysis. A 10 gm aliquot is prepared for the determination of gross β activity, as described in the preceding section, and permits the detection of the desired concentrations of all isotopes except strontium-90 and iodine-131. Approximately 10% of all the various biological samples are large enough to permit detection of the desired concentrations of strontium-90 and iodine-131. These large samples are analyzed specifically for strontium-90.

Standardization. The efficiency of any particular counting arrangement is a function of the β energy. No *a priori* assumption can be made about the energy distribution in the gross β activity of environmental samples. The two counters used in this survey are calibrated with strontium-89 (1.48 Mev β) and thallium-204 (0.76 Mev β). The efficiency of each counter for β spectra of these two maximum energies is the same within the error of measurement, and presumably the efficiency of each is nearly constant for spectra of

intermediate energies. Each counter is standardized daily with a thallium-204 source. The gross concentrations reported are therefore in microcuries of activity equivalent to β emitters in the energy range of 0.76 to 1.48 Mev.

Results

Gross β Analyses. Table II summarizes the overall average concentration of radioactivity in each medium for the year, 1958. The last column in the Table, Confidence Interval, represents two standard errors. The concentrations of radioactivity in rain given in Table II are the totals of soluble and insoluble material. The insoluble activity represents about one-quarter of the total.

Radiochemical Analyses. Table III summarizes the results of the radiochemical analyses by element. In every sample the absolute amount of each radioelement was very small and near the detection limit of the counters. The 95% confidence interval for these measurements was about 50% of the observed count. The last column in Table III gives the fraction of the total β activity in fission products produced by a nuclear detonation expected to be present 20 to 60 days after the detonation.[11] Comparison of the calculated fractions with the observed fractions, given in the next to the last column of Table III, supports the belief that the major portion of the environmental radioactivity found in this survey results from nuclear detonations. Further support for this not unreasonable belief is provided by the rough estimates of half-life obtained from successive gross β counts on many of the samples.

The disparity between the observed and expected cesium fractions in Table III presumably results from the non-specific sulfuric acid leach for cesium. Partly as a consequence of this development, routine soil analysis for cesium by this method has been discontinued.

TABLE II

Comparison of Average Concentrations of Radioactivity by Media for 1958

Medium	Average concentration	Confidence interval
Grass	25. $\times 10^{-6}$ μc gm	5.4 $\times 10^{-6}$ μc/gm
Juniper	22.	4.7
Plankton	16.	8.4
Aquatic plants	15.	3.8
Cabbage	9.2	3.1
Earth	6.7	1.9
Surface sediment	6.0	1.4
Benthos	4.8	1.6
Mammals	3.6	0.73
Apples	2.6	1.1
Fish	2.5	0.41
Rain	10. $\times 10^{-3}$ μc/cm^2-day	3.0 $\times 10^{-3}$ μc/cm^2-day
Surface water	2.7 $\times 10^{-3}$ μc/ml	0.91 $\times 10^{-3}$ μc/ml
Underground water	0.87	0.24
Airborne dust	8.8 $\times 10^{-12}$ μc/ml	4.9 $\times 10^{-12}$ μc/ml

TABLE III

Summary of Radiochemical Analyses by Element

Radioelement	Number of samples analyzed	Number of positive samples[a]	Average % of gross β activity	Calculated % of gross β activity[b]
Barium	5	5	12. %	10 to 4%
Cesium	86	33	7.5	0.1
Iodine	245	18	3.5	8 to 0
Potassium	1	1	5.2	—
Strontium	5	2	6.2	6 to 10

[a] The number of samples with activities exceeding the detection limit of the counters.

[b] Fraction of the total β activity in fission products present 20 to 60 days after a nuclear detonation.[11]

Discussion

Media. It is clear from the summary of yearly averages given in Table II that the levels of radioactivity fall into three categories, each significantly different from the others: biota, water and airborne dust. Among the biota, grass, juniper, plankton and higher aquatic plants are appreciably more radioactive than the other biological forms. The higher animals, fish and mammals, contain distinctly less radioactivity than most other biological materials. A large part of the variability exhibited by plankton results from the small sample sizes and the consequent counting uncertainty.

Among the water group, underground water is significantly less active than surface water. The activity in rain water is expressed in units of μc/cm^2-day and is therefore not directly comparable to the other two.

Location. No systematic differences among locations are apparent for most media. Surface water, however, is an exception. The concentrations of radioactivity in Swan Creek vary so greatly that comparison to the other surface waters is of doubtful value. The Reactor Lagoon has the highest average concentration of radioactivity of any of the surface waters, followed by the two Lake Erie locations; Trenton Channel exhibited the lowest concentration among the surface waters sampled. These differences are significant and probably reflect local differences in drainage, hydrological and meteorological conditions.

Time. Most of the media sampled show no clear cut trends with time during 1958. Two exceptions

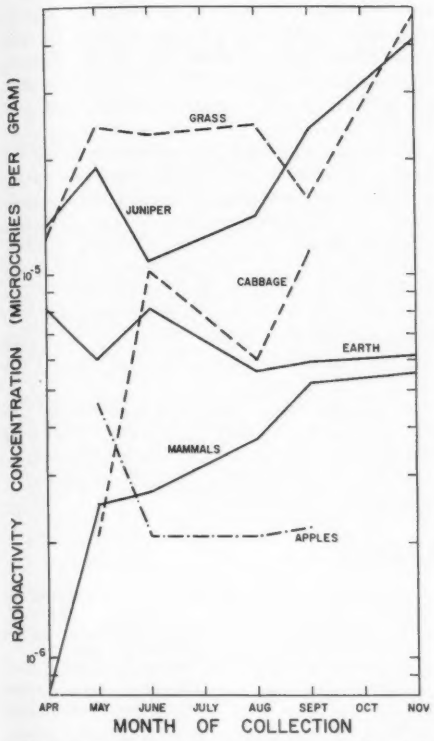

FIGURE 2. Radioactive content of terrestrial biota vs time.

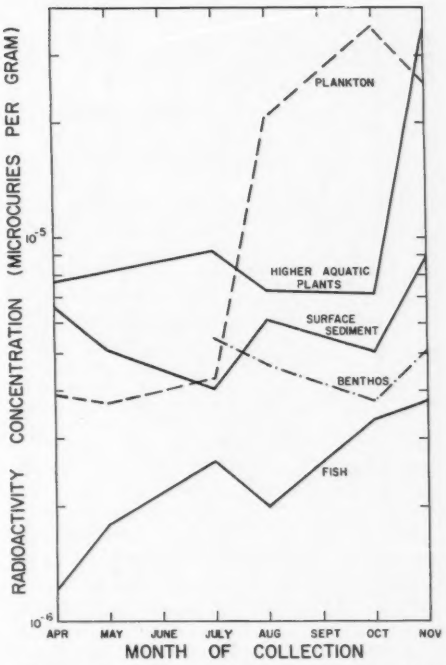

FIGURE 3. Radioactive content of aquatic biota vs time.

are mammals and fish which both show a continuing upward trend throughout the year. Figures 2 and 3 show the levels of radioactivity in biota through 1958. This trend may indicate either that these organisms are gradually approaching equilibrium with their radioactive environment, or that there is a seasonal variation in the biological year.

Figures 4 and 5 show the variations of radioactivity in water and rain, respectively. The radioactive content of both media increased during October and November, and subsequently decreased in December. The flurry of nuclear detonations early in the fall of 1958 coincides with the observed activity increase in water and rain. There is no obvious explanation for the sharp decrease in December.

Cost. Very few figures are available on the cost of a Survey of the type described here. The following figures may be of interest. The costs for the year, 1958, averaged about $3,000 per month, divided as follows: consumable materials, 25%; travel to collect samples, 5%; labor 70%. Of the

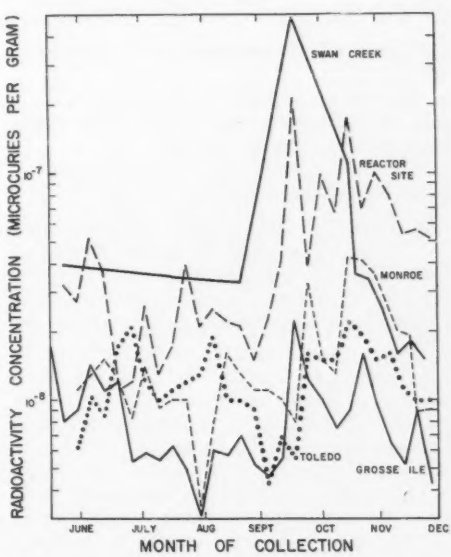

FIGURE 4. Radioactive content of water vs time.

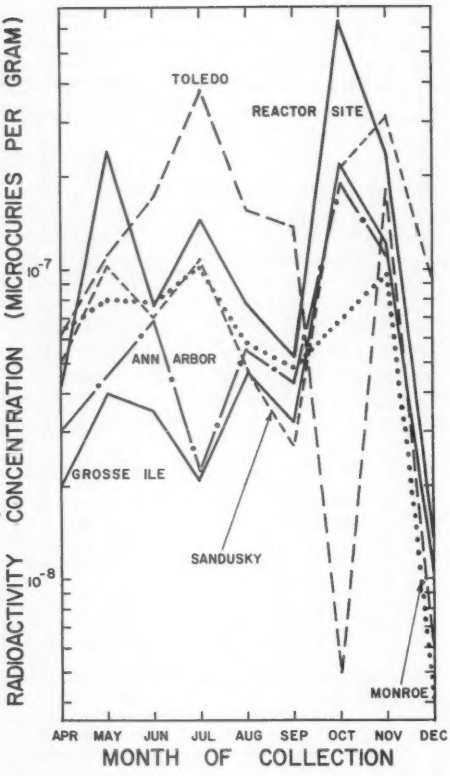

FIGURE 5. Radioactive content of rain vs time.

70% taken by labor, 10% went for sample collection, 25% for sample analysis, 20% for data handling, and 15% for supervision.

Acknowledgments

A survey of the kind reported here, cutting as it does across many scientific disciplines, demands knowledge and experience that no two individuals can hope to possess. The authors are particularly fortunate in having had the advice of many professors at the University of Michigan in the selection of the types, numbers and locations of sampled media. Among these are N. G. Hairston (terrestrial ecology), E. W. Hewson (meteorology), G. H. Lauff (aquatic ecology), and J. T. Wilson (geology).

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Radioactive Trash Disposal at Los Alamos*

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Introduction

THIS report will attempt to describe the methods used at Los Alamos for the disposal of solid radioactive waste material. The principal contaminant is Plutonium which is a long lived alpha emitter, because of the high toxicity of this element it is necessary to dispose of such contaminated trash by burial in disposal pits. Although the methods discussed in this report are felt to be adequate for low level alpha activity, a different approach to the problem would have to be taken if high level beta-gamma activity were present in the contaminated waste. When it is necessary to dispose of materials that are highly contaminated with alpha activity, special care is taken in the packaging, transportation, and ultimate disposal in the burial pits.

Origin and Nature of Contaminated Trash

The bulk of routine alpha contaminated trash comes from laboratories where radioactive materials are handled. Rubber gloves, absorbant paper, glassware, paper towels and other similar material constitute the major portion of this trash. Considerable amounts of trash are handled as contaminated waste due to the fact that the trash comes from the general laboratory areas. The alpha activity of this trash is low, however, it is more economical to dispose of such waste in this manner than to attempt to separate contaminated from uncontaminated material.

Laboratory buildings as well as the fixed equipment in these buildings may also become contaminated so that when these are torn down or remodeled the scrap material must be considered contaminated trash. Burnable portions of this trash are taken to a separate pit and burned. The burning operation is supervised by a Health Division Monitor and a member of the Fire Department. A permit to burn the combustible material is issued by the Fire Department after they have determined that the condition of the wooded area adjacent to the disposal pit is suitable for the burning operation. A laborer is detailed to watch the operation to insure that combustion is complete. All burning is done during the daytime so as to avoid the necessity of maintaining a fire watch at night. The Health Division Monitor directs the placement of material at the burning pit. His other duties include monitoring personnel and equipment and taking air samples downwind from the burning operation. The non-burnable material is taken to the regular disposal pit and buried.

Methods of Packaging Trash

Two methods of packaging trash are used at Los Alamos. The first method is used at about a dozen different laboratory sites and is the older of the two methods being used. The contaminated trash is placed in cardboard cartons. When these are full the tops are sealed with two- inch masking tape. This tape has been found to be the most satisfactory type of sealant and it affords a fairly tight seal for the boxes until they are taken to the burial pits. Each box, after it has been sealed, is marked on the outside with the date and location of the origin of the trash. The sealed boxes are then removed from the laboratory buildings by janitors and placed in Dempster Dumpster containers.

The second method used for packaging contaminated trash involves the use of plastic bags. The waste material is placed in metal trash cans which have 5 mil plastic bags as liners. When these cans are full the plastic bags are removed, sealed, marked and placed into a large trash dolly. This dolly also has a 5 mil plastic bag liner, and when it is filled this liner is removed, sealed, marked with the date and origin of the waste material and taken outside of the laboratory building and placed in a Dempster Dumpster container. This method of using plastic bags for trash containers has several advantages over the use of cardboard boxes. The time needed to prepare cardboard boxes is roughly twice that for plastic bags. The waste material, if wet, may seep through the boxes and contaminate floors, whereas, the plastic bags will contain moist material much better than boxes. At the burial pits where the trash is exposed to the weather it has been found that the plastic bags contain the material much better than the boxes.

At two laboratory sites liquid radioactive wastes are processed. The end product is a sludge

* This study was performed under the auspices of the Atomic Energy Commission.

FIGURE 1. Pit used for burning scrap building material.

FIGURE 2. Removal of filled plastic bag.

which has a very high alpha activity level and is also quite heavy. This sludge is put into 55 gallon steel drums for hauling to the disposal pits.

Transportation of Contaminated Trash

Dempster Dumpster containers are now being used throughout the laboratory for holding contaminated and non-contaminated trash. The containers which are used exclusively for contaminated trash are prominently marked with six inch yellow bands around the tops and the loading doors have the wording "RADIOACTIVE TRASH ONLY" painted on them. When the containers are filled they are hauled to the disposal pit and emptied. The Dempster Dumpster trucks used for hauling these containers have been monitored and no detectable contamination has been found on them. The containers are also monitored at intervals and to date none have been found to have detectable contamination.

A truck is used one day per week for hauling the 55 gallon steel drums containing the highly contaminated sludge. This truck is also used for hauling condemned government property and other contaminated material that cannot be placed in the Dempster Dumpster containers. The truck bed and the hydraulic tail gate have a small degree of alpha contamination. For this reason this truck is restricted to hauling only contaminated material.

A Health Division Monitor supervises the transportation of contaminated trash when the hauling is done by truck. His duties include radiological supervision of the workmen such as making certain they are wearing protective clothing and issuing film badges when these are required. He makes any necessary personnel as well as area surveys to determine contamination and radiation levels. At the pick up site the monitor supervises the actual loading of the material onto the truck. Every effort is made to package material so that contamination will not escape during handling and transportation to the disposal area. The monitor checks the packages for excessive radiation before they are picked up and may require that they be repackaged. The Dempster

FIGURE 3. Unloading Dempster Dumpster at disposal pit.

Dumpster containers are believed to be adequate in holding packaged trash during transit to the burial pit and for this reason the monitor does not accompany the container on its way to the pit.

At the disposal pit the monitor unlocks the access gate to the pit and observes the unloading operation as well as the location of the material within the pit. Along the side of the pit are numbered posts, these posts are used as cross references to locate material within the pit. When the unloading operation has been completed, the monitor re-locks the access gate to the pit. The gate is kept locked at all times except when a Health Division Monitor is present at the pit.

A permanent notebook is used to log information as to the locaion and nature of the material placed in the dispoasl pit. Information kept in this book includes the disposal area designation, pit number, layer number within the pit, post number, a general description of the material, the date of disposal as well as the site where the material came from. Since the packaged material has the date and origin marked on the outside of the container, one can use this logbook as a reference to locate material placed in the pit with a fair degree of accuracy. The reason for marking the containers and logging in their ultimate location within the pit is that there is always the possibility that accountable material or government property might inadvertently be sent to the pit along with other waste material.

Disposal Pit Description

The laboratory Engineering Department has prepared maps that show the exact geographical location of each disposal area. Each area has had permanent survey markers located at each corner. The physical dimensions of the disposal pits are roughly thirty feet deep, one hundred feet wide and five hundred feet in length. The excavated volume amounts to about forty-four thousand cubic yards.

Prior to the excavation of disposal pits, the United States Geological Survey is asked to examine the proposed site location and their advice as to the fitness of the location is followed. Such factors as seepage, ground water movement, geology of the site location and climatic conditions are carefully considered before using an area for a disposal site. For example, they requested the depth of the pits to be kept to about thirty feet due to the fact that the pits are located in a Tuff rock strata which is about fifty feet thick. This depth means that the floor of the pit is still twenty feet above the bottom of the caprock. Ease of excavation and access into and out of the pit are the reasons for the five hundred foot length. The width of one hundred feet is found to be convenient for maneuvering trucks and dirt hauling equipment inside the pit.

Each disposal area that has been or is now being used for contaminated trash disposal is fenced with chain-link type fencing. The gates to these areas are kept locked and access to the areas is controlled by the Health Division. Radiation warning signs are posted at frequent intervals on the fencing around each area.

Trash in the pit is covered on an average every two or three months with dirt, the dirt cover is about six inches above the trash layer. The final layer of trash is covered with a minimum of three

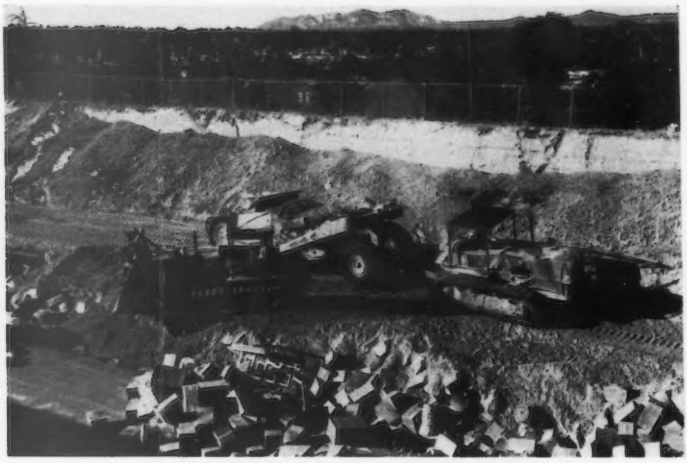

FIGURE 4. Covering trash at disposal pit.

feet of dirt. Compaction of trash is also accomplished by the covering operation so that the volume is probably reduced by at least one third by the heavy dirt hauling equipment that is used for the covering operation. Conservation of pit space is very desirable and for this reason material and dirt cover placement are supervised closely.

Every effort is made to prevent a fire from starting in the exposed trash and covering the trash with dirt affords a measure of fire protection. Acids and other reactive chemicals are picked up and disposed of at another area by the Laboratory Safety Group. The layer of contaminated trash in the pit is maintained at about three feet in thickness. Cardboard boxes and other packaged trash is not allowed to pile up as this might afford a condition for spontaneous combustion. In the event that a fire should start at the pit the single layer technique would make the job of putting out the fire much easier.

The rate at which these pits are filled has varied from year to year. Remodeling activities at the Laboratory as well as demolition of old laboratory buildings have contributed heavily to the volume of contaminated trash. The annual volume of contaminated trash varies from twenty five hundred to three thousand cubic yards of material; this rate of filling will give an average use of two years for a disposal pit.

Contaminated Trash Disposal Costs

The costs of disposing of radioactive trash by burial have been determined as well as is possible. In 1956, this averaged $27.00 per cubic yard and in 1957, this average was $23.00; in 1958, it is estimated that this cost will be about $20.00. The cost reduction anticipated for 1958 is due in part, to the use of Demptser Dumpster containers for hauling the major portion of contaminated trash. Prior to 1958, a truck was used exclusively to haul this material to the disposal pit. The cost per box was found to be about $0.50 when the hauling was done by the truck and when Dempster Dumpster containers were used this cost was reduced to about $0.25.

There are several factors that contribute to the disposal costs. The packaging operation is one of the more expensive items. A time study was made of the operation and it was found that about fifty man-hours per day is needed to package the contaminated trash at the various laboratory sites. This job involves preparing the cardboard boxes

TABLE I

Contaminated Trash Disposal Costs

	1956	1957	1958(½ yr.)
Packaging materials:	$35,850	$38,413	$18,081
Transportation costs:	21,942	23,984	11,928
Disposal pit costs:	11,547	10,693	4,972
Total:	$69,339	$73,090	$30,981
Trash Volume			
Cubic yards:	2,537	3,164	1,528
Cost per cubic yard:	$27.00	$23.00	$20.00

by sealing the bottoms of the boxes with two-inch masking tape. When the boxes are filled, the tops of the boxes are also sealed with tape. The boxes are then marked, carried outside of the laboratory building and placed in the Dempster Dumpster container.

Packaging materials are not too expensive, but even here a large number involves considerable expense. The most recent price for cardboard boxes used to hold trash was 19¢ per box and since about 26,000 boxes are used per year, this amounts to about $4,000 per year. Masking tape is used quite extensively for sealing boxes, plastic bags and as a covering material in some cases. Over 1,400 rolls of tape are used per year at an annual cost of about $900.00. Plastic bags in several sizes are used as liners for trash dollys and trash cans. Several thousand bags are used each year at an annual cost of about $1,000.00.

Excavation of the disposal pits is expensive. The most recent pit cost over $12,000 or an average of about $0.30 per cubic yard. The heavy equipment charges, wages and overhead as well as maintenance are included in this cost item. The covering operation costs vary but an average of thirty-two man hours is used to complete a covering job. The total charges for this work includes the heavy equipment charges, wages, maintenance and overhead.

Disposal of contaminated trash and the trash covering operations are supervised by a Health Division Monitor. The work takes up about 1,000 man-hours per year and the total cost would include wages, overhead and the use of a vehicle for traveling to and from the disposal pits.

Data Explanation

Attached to this report are data which attempt to show the cost of disposal of contaminated trash. The figures presented are close approximations only and should be considered as such. Investigations into disposal costs were started in 1956 so only the past two and one-half year's operations can be compared. Continued efforts to reduce costs are being made and there is little doubt that future costs can be considerably less than the present figures.

Summary

The present method of disposal of radioactively contaminated waste material is under the control of H-1 Group, Health Division. Methods of packaging, transportation and burial of this trash are being improved. This should make the operation less costly and safer in the future. This is being brought about by improved packaging techniques, use of Dempster Dumpster containers for hauling the trash and continued surveillance over the entire operation.

Acknowledgments

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Industrial Ventilation Manual

THE AMERICAN CONFERENCE of Governmental Industrial Hygienists has announced the publication of a new, enlarged, completely re-edited 1960 Sixth Edition of the *Industrial Ventilation Manual*. This volume contains information on low velocity systems, new hood design diagrams, pressure-volume-horsepower curves for fans, a new table of corrosion resistant properties of plastics, revised section on testing of ventilation systems, new material on radiant heat, high and low temperature psychrometric charts, and numerous other useful features.

The first edition of this manual was issued in 1951. Since that time approximately 19,000 copies have been distributed in this country and abroad. The recommended practices contained in this excellent work are recognized and approved by numerous municipal, state, and federal governmental agencies. The generous use of a large number of drawings, illustrations, and examples of various situations which may be encountered is a notable feature of this publication.

The manual costs $7.00 with hardcover and $4.00 with flexible cover. (Discount allowed for quantity purchases.) Address inquiries or orders to: Committee on Industrial Ventilation, P.O. Box 453, Lansing 2, Michigan.

Contamination Resulting from the Release of Radioactive Liquid Wastes to the Tennessee River System

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Introduction

THE high-volume, low-level radioactive liquid wastes originating at Oak Ridge National Laboratory are dispersed into the Tennessee River system by way of White Oak Creek and the Clinch River. Releases are controlled so that the resulting average concentration in the Clinch River complies with permissible levels set forth by the National Committee on Radiation Protection and the International Commission on Radiological Protection. The amount of radioactivity leaving White Oak Creek is measured and concentration values in the Clinch River are calculated on the basis of the dilution provided by the river. Radioactive materials are reconcentrated by selective adsorption on clays and by biological action of certain organisms. Such processes, while removing radioactivity directly from the water, tend to concentrate the activity on the bottom sediments. By measuring the accumulation of radioactive materials on the bottom sediment of the rivers, information can be obtained relative to the dispersal of wastes and their subsequent reconcentration in the environment.

Measurements have been made of the radioactivity in the water, and of the accumulation of radioactivity on the bottom sediment of the Clinch and Tennessee Rivers (1) to determine the degree of dispersal and concentration of radioactivity in the river system, and (2) to evaluate the hazard to the general population resulting from such releases.

Annual surveys of the radioactivity on the bottom sediment of the Clinch and Tennessee Rivers have been made since 1951. The surveys for 1951, 1952, and 1953 have been reported by Garner and Kochtitzky.[1] This paper summarizes the findings from 1954 through 1958.

Radioactivity in the River Water

Liquid wastes leaving the Laboratory were sampled at a number of locations. Daily samples were taken where the effluent leaves the Laboratory, at a point where the wastes enter the public waterway, and at the nearest population center downstream from the Laboratory. Stream gauging operations were carried on continuously by the USGS in order to obtain the dilution factors for evaluating the concentration of wastes in the river.

Samples were analyzed for gross beta activity and aliquots of daily samples were composited into weekly and monthly samples for more detailed analysis. Weekly composites were analyzed for plutonium content and monthly samples were analyzed for long-lived fission products. The concentration of radioactivity in the Clinch River, where water becomes available for public use, was obtained by multiplying the specific concentration found in White Oak Creek by a dilution factor obtained from the ratio of White Oak Creek flow to the Clinch River flow at the point of entry of the wastes. The calculated concentration thus obtained in the Clinch River assumes uniform mixing of the two streams.

The fraction of total beta activity comprised by each isotope was determined from analysis of long-lived radionuclides contained in the effluent. A weighted average MPC_w value for the mixture of radioisotopes was calculated on the basis of isotopic distribution determined from chemical analysis. The weighted average MPC_w value for the mixture is calculated by the following formula:

$$MPC_w = \frac{\Sigma f_i}{\Sigma \frac{f_i}{MPC_i}}$$

One notes from Figure 1 that the yearly average calculated concentration of radioactivity in the Clinch River has not exceeded the weighted average MPC_w value for continuous use by the population in the neighborhood of a controlled area.

In late 1956, collection of daily samples from the Clinch River was started near Kingston, Tennessee, a point approximately 16 miles downstream from the point of entry of the wastes, to

* Operated by Union Carbide Corporation for the U. S. Atomic Energy Commission.

determine the levels of radioactivity in the water at the nearest population center. The daily samples were collected for a three month period at which time a 20-gallon composite was filtered and the filtrate concentrated. The concentrated filtrate and residue were analyzed by gamma spectrometry and radiochemical techniques to determine the levels and composition of the activity existing in the river at the above point. The major long-lived radioisotopes found by the analyses were Co^{60}, $Zr\text{-}Nb^{95}$, Cs^{137}, Ru^{106}, Ce^{144}, and Sr^{90}. The Sr^{90}, which is by several orders of magnitude the most hazardous of the elements listed above, comprised about 50 per cent of the activity detected.

The average concentration of radioactivity in the river from 1956 through 1958 was found to be 7.5×10^{-8} $\mu c/cc$. Based on the distribution of the radionuclides present and the levels permitted by the NCRP and the ICRP for continuous use by the population in the neighborhood of a controlled area, the calculated weighted average MPC_w value in the river for the isotopes released and the time in question was 2.4×10^{-7} $\mu c/cc$. Thus, the activity levels detected in the water were only about 30 per cent of the maximum permissible level.

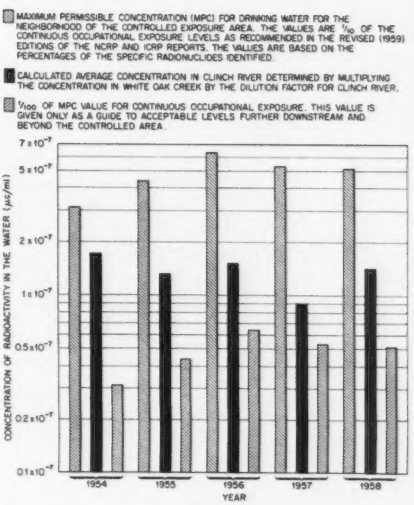
MAXIMUM PERMISSIBLE CONCENTRATION (MPC) FOR DRINKING WATER FOR THE NEIGHBORHOOD OF THE CONTROLLED EXPOSURE AREA. THE VALUES ARE 1/10 OF THE CONTINUOUS OCCUPATIONAL EXPOSURE LEVELS AS RECOMMENDED IN THE REVISED (1959) EDITIONS OF THE NCRP AND ICRP REPORTS. THE VALUES ARE BASED ON THE PERCENTAGES OF THE SPECIFIC RADIONUCLIDES IDENTIFIED.
CALCULATED AVERAGE CONCENTRATION IN CLINCH RIVER DETERMINED BY MULTIPLYING THE CONCENTRATION IN WHITE OAK CREEK BY THE DILUTION FACTOR FOR CLINCH RIVER.
1/100 OF MPC VALUE FOR CONTINUOUS OCCUPATIONAL EXPOSURE. THIS VALUE IS GIVEN ONLY AS A GUIDE TO ACCEPTABLE LEVELS FURTHER DOWNSTREAM AND BEYOND THE CONTROLLED AREA
CONCENTRATION OF RADIOACTIVITY IN THE WATER (μc/ml)
7 x 10⁻⁷
5 x 10⁻⁷
2 x 10⁻⁷
1 x 10⁻⁷
0.5 x 10⁻⁷
0.2 x 10⁻⁷
0.1 x 10⁻⁷
1954
1955
1956
1957
1958
YEAR

FIGURE 1. Concentration of radionuclides in Clinch River (1954–1958) and the calculated MPC values.

Radioactivity in Bottom Sediments

When radioactive waste materials are released to the environment, the hazard evaluation program should continue beyond the point of release as certain natural processes may reconcentrate waste materials to a potentially hazardous degree. Over the past several years extensive measurements have been made of the radioactivity in the bottom sediment of the Clinch and Tennessee Rivers in order to determine the degrees of dispersion and fixation of radioactive waste materials in the bottom sediment.

Surveys were made annually in the Clinch and Tennessee Rivers for a distance of approximately 200 miles. Figure 2 shows the section of the Tennessee River system over which the surveys were made. It will be noted that the wastes enter the Clinch River at CRM (Clinch River Mile) 20.8. Measurements were made in the Clinch River from CRM 27.5 (which is 6.7 miles above the point of entry) to the confluence of the Clinch and Tennessee Rivers, and in the Tennessee River from TRM (Tennessee River Mile) 570.8 to TRM 475.1. The 1957 and 1958 surveys were extended downstream as far as TRM 354.4.

Cross section surveys were made along silt ranges which had been mapped previously by the Tennessee Valley Authority. A cross section survey consists of taking gamma measurements and sediment samples at predetermined intervals along the traverse from one bank of the river to the other. Sampling in the Clinch River was done along the traverse at fifty foot intervals. Due to navigation problems existent in the Tennessee River and its reservoirs, sampling below CRM 4.7 was performed along a traverse divided into ten equi-distant parts. Cross sections were taken every two miles in the Clinch and approximately every ten miles in the Tennessee River.

A gamma detecting device known as *flounder*, is shown in Figure 3. It consists of twelve GM Tubes connected in parallel to a battery powered decade scaler, and was used to measure the gamma radiation from the bottom sediment. At each sampling point along a cross section, the flounder was lowered from the boat and allowed to come gently to rest on the bottom. While the gamma count was in progress a sample of bottom sediment was obtained with an Eckman Dredge, the sample being taken at the opposite end of the boat to prevent stirred up sediment from influencing the gamma count.

Baseline background data used in the evaluation of flounder measurements were determined in Norris and Fort Loudoun Reservoirs—two bodies of water presumably free of radioactive contamination. Gamma readings were taken at five-foot intervals in the water, from the surface to a depth greater than 100 feet and a curve of counts per second (c/sec) versus depth was plotted. The data was used to correct the downstream readings for background. Bottom sediment readings in these

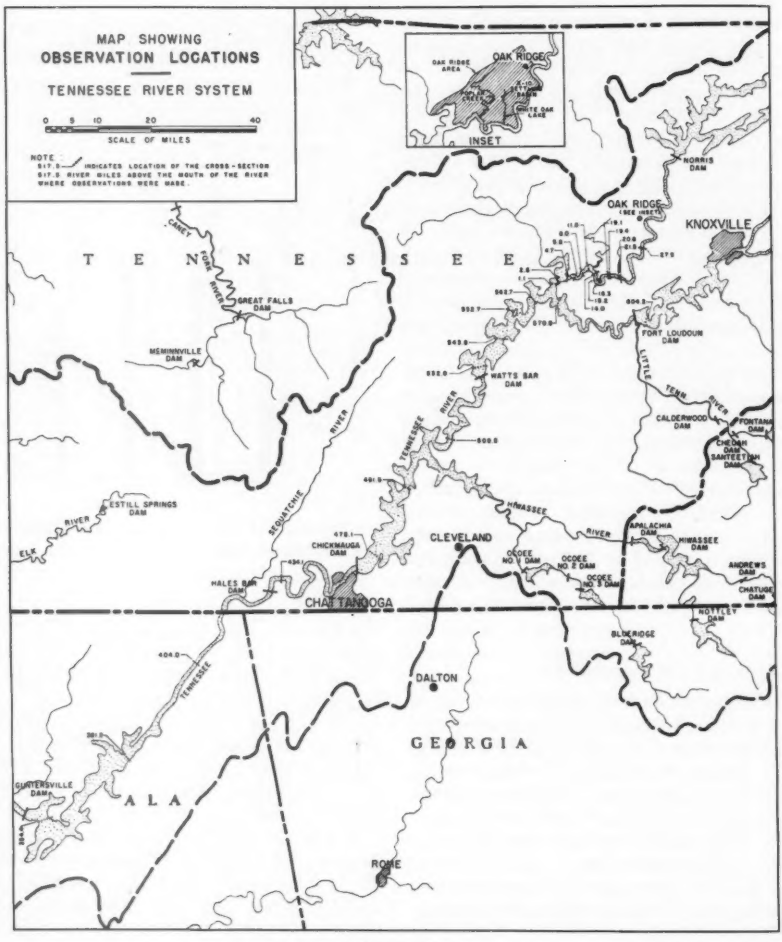

FIGURE 2.

reservoirs provided silt background data for comparison of readings downstream. The silt background readings ranged from 7 c/sec in 1954 to 13 c/sec in 1958. The four year average was approximately 10 c/sec.

The flounder was calibrated in milliroentgens per hour (mr/hr) with a standard radium source. The calibration was repeated each year to determine the sensitivity of the instrument and to permit direct comparison of the data from year to year. Calibration of the instrument from year to year was consistent and indicated that 100 c/sec was equivalent to 0.06 mr/hr of gamma radiation.

The gamma measurements made on the bottom sediment were averaged, after correction for background, for each cross section. Plots of the average gamma count versus river mile for the Clinch and Tennessee Rivers were made. The readings obtained with the flounder ranged from 4–7 c/sec at CRM 27.5 to an average of 181 c/sec for the cross section taken at CRM 8.0. The readings of 4–7 c/sec were in the upper reaches of the Clinch River on rocky shoal bottom and are somewhat lower than the silt background of the uncontaminated streams.

Figure 4 shows that the gamma count rate gradually increases downstream from the point of entry into the Clinch River. The peak reading occurred at mile 11.0 during 1954 and 1955, and at mile 8.0 during 1956, 1957, and 1958. Below CRM 11.0 and CRM 8.0 the gamma count was

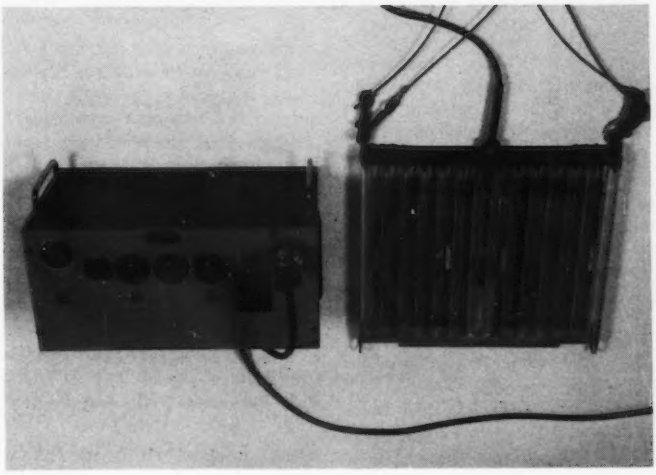

FIGURE 3.

relatively constant except for low counts at CRM 4.7 and CRM 2.6. At these two points, the silt seems to have been scoured from the river bottom, thus resulting in low counts. The increase in activity downstream from the point of entry of the wastes is probably due to the fact that during the fall and winter months considerable current is present in the Clinch where the wastes enter. It has been theorized that the current prevents the silt from settling, carrying it downstream to be deposited later as the current decreases. The scouring phenomenon was encountered repeatedly during the surveys, and it was noted that locations where any restriction in the river channel was sufficient to cause an increase in velocity showed this effect.

The level of activity drops off markedly upon entering the Tennessee River and continued to decrease downstream, Figure 5. This was to be expected due to the dilution of the Clinch water by the Tennessee and the subsequent deposition of the silt over a much larger bottom area. The decrease in activity due to decay is negligible since the time required for wastes to travel to the Tennessee River is short compared to the half-lives of the radionuclides present.

The distribution of activity along a traverse was, in general, proportional to the depth of water. This was especially true in the reservoirs and in the lower reaches of the Clinch River where most of the activity was found in the main channel. Farther up the Clinch, the picture was somewhat complicated by the numerous sharp bends in the river course and by the current in the river. Here the activity varied depending upon whether the traverse was taken on a straight stretch or on a bend in the river and whether the stream bed was uniformly deep, or deep on one side and shallow on the other.

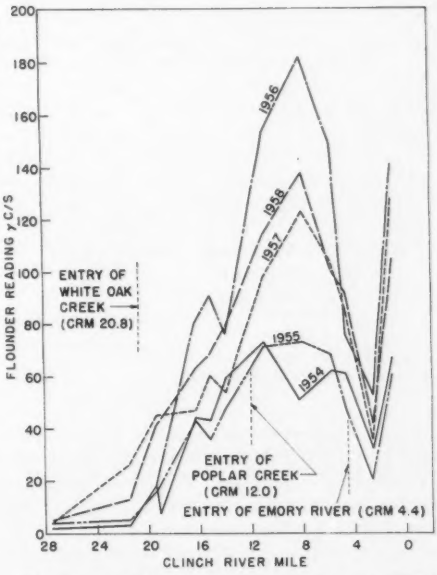

FIGURE 4. Gamma count at surface of Clinch River sediment.

The level of activity in both the Clinch and Tennessee Rivers have shown an increase from 1954 through 1958. The overall increase in gamma

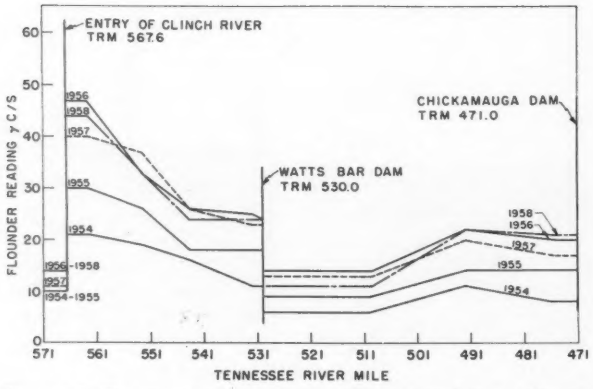

FIGURE 5. Gamma count at surface of Tennessee River sediment.

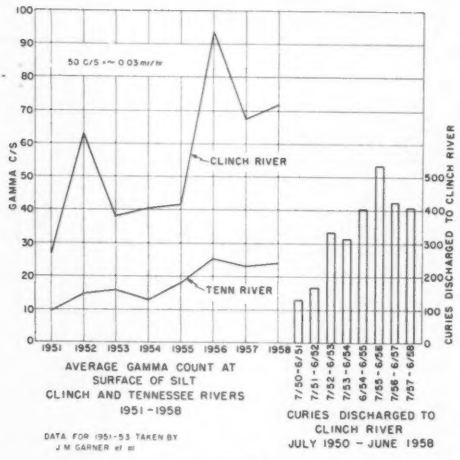
50 C/S ≈ 0.03 mr/hr
CLINCH RIVER
TENN RIVER
GAMMA C/S
CURIES DISCHARGED TO CLINCH RIVER
AVERAGE GAMMA COUNT AT SURFACE OF SILT CLINCH AND TENNESSEE RIVERS 1951-1958
DATA FOR 1951-53 TAKEN BY J.M. GARNER et al
CURIES DISCHARGED TO CLINCH RIVER JULY 1950 - JUNE 1958

FIGURE 6.

count rate with time may best be seen by reference to Figure 6. Here the average count rates for both the Clinch and Tennessee Rivers are plotted by years for the period 1951 to 1958. Figure 6 also reflects the number of curies discharged to the Clinch River for the corresponding periods of the surveys. It should be noted that, while there are fluctuations in the levels of activity, the general trend in is an increasing direction. The correlation of the levels detected with the curies discharged is good. The relatively large increase in activity observed in the Clinch River during the 1952 survey was attributed in part to large releases of short lived materials just prior to the 1952 survey. The 1953 survey showed an appreciable drop in activity. The increase observed from 1955 to 1956 was due primarily to the draining of White Oak Lake with the attendant scouring of contaminated silt from the lake bottom. The lake silt was discharged to the Clinch during the fall of 1955 and consisted of long-lived activity which would have decayed very little before the 1957 survey. The decrease in count rate observed in 1957 was attributed to the relocation of the contaminated silt by scouring or the covering and consequent shielding of the activity by the uncontaminated silt from upstream.

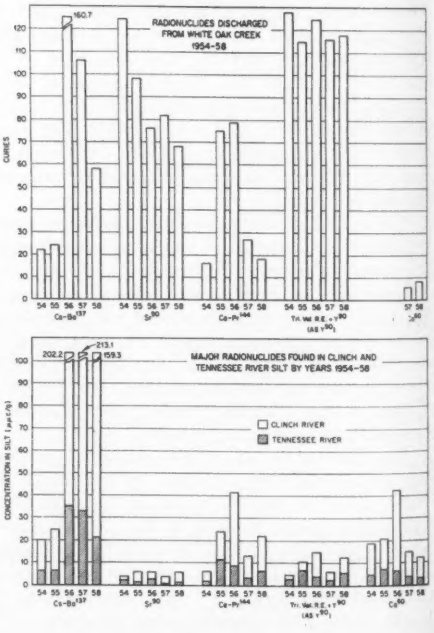
RADIONUCLIDES DISCHARGED FROM WHITE OAK CREEK 1954-58
CURIES
MAJOR RADIONUCLIDES FOUND IN CLINCH AND TENNESSEE RIVER SILT BY YEARS 1954-58
CLINCH RIVER
TENNESSEE RIVER
CONCENTRATION IN SILT (μμc/g)

FIGURE 7.

Identification of Bottom Sediment Activity

Bottom sediment samples were composited for each cross section and analyzed by radiochemical techniques to identify the long-lived radionuclides present. The samples were analyzed for cesium, strontium, cerium, the tri-valent rare earths, ruthenium, niobium, zirconium, and cobalt. Silt from Fort Loudoun Reservoir, presumably containing no fission products from Oak Ridge Operations, was analyzed to obtain background levels of activity for the silt of the area.

The major radionuclides contained in the bottom sediment are cesium, cerium, and cobalt with smaller amounts of strontium, yttrium, the trivalent rare earths, ruthenium, and zirconium. The concentrations of the major radionuclides occurring in the silt of the Clinch and Tennessee Rivers for the years 1954 through 1958 are shown in Figure 7. The total number of curies of each radionuclide discharged to the river for corresponding periods is presented for comparison. The best correlation of radionuclide discharged to radionuclide concentration found in the bottom sediment was shown by cesium. This is not surprising when it is noted that cesium is readily removed from water by adsorption on silt particles.

In general, the concentration of radionuclides in the silt increased from 1954 through 1956 with the greatest increases being shown by cesium, cerium, and cobalt. The concentration of radionuclides, with the exception of cesium, decreased in 1957 from that of the previous year. In 1958, however, the cesium and cobalt concentration decreased while the cerium concentration exhibited a slight increase. The very large increase in the amount of cesium discharged to the Clinch in 1956 and the high concentration detected in the silt from 1956 through 1958 is again probably due to the draining of White Oak Lake in the fall of 1955.

Summary

The concentration of radioactive materials in the water of the Clinch River resulting from waste releases from ORNL, for the period covered, averaged 7.5×10^{-8} μc/cc. The major radionuclide present in the water, both activity and hazard wise, was Sr^{90}. The concentration of radioactive materials on the bottom sediment dropped off markedly after the first 20 miles, where the Clinch enters the Tennessee River. The highest average level of radioactive contamination for a particular traverse resulted in an average dose rate of about 0.1 mr/hr on the river bottom. This level was about 18 times background and was located approximately 12 miles below the entry of the wastes into the Clinch River. The level of activity in the Tennessee River was about twice background at 100 miles below the point of entry of the wastes and approaches background at 150 miles downstream, where fission products were still detectable by radiochemical analysis. The major radionuclides present in the bottom sediment were cesium, cerium, and cobalt.

This study indicates that activity levels in the water and bottom sediments of the Clinch and Tennessee Rivers resulting from waste releases are well below those recommended by the NCRP and the ICRP and, thus, do not represent a hazard to the general population. However, continuing vigilance must be maintained to insure that build-up or reconcentration of the radioactive materials do not create a problem at some future date. It should be kept in mind, too, that in general there are three classes of wastes—liquid, solid, and gaseous. All three types of waste from ORNL are monitored and kept under control at or below the level set by the NCRP and the ICRP.[2]

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Protecting and Cleaning Hands Contaminated by Synthetic Fallout under Field Conditions

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Introduction

RADIOACTIVE contamination of the skin of personnel following a nuclear weapon detonation or a radiological accident can constitute a serious health problem. However, the study of contamination and decontamination until now has been limited to laboratory tests on skin. No information is available on the relative merits of cleaning materials used under field conditions. Prevention through the use of rubber gloves is desirable, but under field conditions this may not always be practical or possible. Also, contaminants have been known to penetrate surgeon's gloves.[1] Therefore, it is necessary to have alternate means of protecting or cleaning hands which are vulnerable to contamination under field conditions.

Various laboratories that utilize radioisotopes in research have published the results of case studies in which the skin of personnel had become accidentally contaminated and required decontamination. Most of these decontaminations were performed with strong chemical reagents which are generally not applicable to field work inasmuch as they require careful supervision to prevent serious skin irritation.

Mild chemical methods for decontamination of the skin were studied at USNRDL in 1949.[2] Two types of solutions which were developed appeared suitable: one type consisted of isotonic neutral solutions of complexing agents, plus a detergent and germicide; the other was an isotonic saline solution at pH 2.0, plus a detergent and germicide. The toxicities of these solutions were studied in 1950;[3] both were found slightly irritating, probably due to the germicide. This study also showed that these solutions tended to increase the absorption into the body of a soluble $Sr^{89}Cl_2$ radioactive contaminant.

At *Operation Castle* the hands of technical personnel and decontamination crews often became contaminated from fallout deposits. Usually the contaminant was removable by scrubbing with soap and water or by scrubbing with a mixture of cornmeal and detergent, but on one particular individual such treatment did not remove the contaminant. An ammoniacal, petroleum-based, waterless hand cleaner was found to be effective in cleaning this individual's hands.

Barrier creams, advertised as giving protection against dermatitis caused by contact agents, such as solvents, grimes, pollens, and irritating plants, are a possible preventive. The use of barrier creams has reduced the problem of skin contamination in one atomic energy plant;[1] but tests using barrier creams to reduce the effects of other contact agents have not been conclusive.[4]

Barrier creams may actually interpose a physical barrier between the skin and potential contaminating agents. The cream, if applied heavily enough, might even act as a shield against alpha and low-energy beta radiation. Personnel from this laboratory who have used various barrier creams found them generally useful for reducing the effort required to clean hands after working with ordinary industrial greases, paints, and grimes; and the creams caused no skin irritation.

USNRDL conducted a land target recovery field test at Camp Stoneman, Pittsburg, California, in September 1956. Full-scale decontamination procedures were used on limited areas contaminated with synthetic fallout; this provided an excellent opportunity to test methods and procedures of hand decontamination. This report describes the experiment which was undertaken. The objectives were to determine the effectiveness of barrier creams in preventing radiological contaminants from adhering to hands and to determine the effectiveness of a waterless cleaner and three experimental solutions in removing contaminants from the skin of the hands.

Experimental Plan

During the land target recovery tests the normal duties of operating personnel included preparing radioactive La^{140} solution, mixing the La^{140} solution with soil to make the synthetic fallout, dispersing the synthetic fallout, radiation surveying, and performing decontamination operations. Selected operating personnel were given the ex-

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† The opinions expressed by the author do not necessarily reflect those of the Navy Department.

perimental protection of a barrier cream prior to entering the contaminated area. Any person returning from the contaminated area with over 500 counts per minute on his hands, as determined by the Radiological Safety Officer, was directed to the hand cleaning center where a sequence of count-clean-count was performed on the palms of his hands using the experimental procedures described below under Cleaning. When the experimental hand cleaning sequence for an individual was completed, he was released to the Radiological Safety Officer for routine personnel decontamination.

CONTAMINANT

Three types of contaminant were used in this experiment. Most of the data on which this report is based came from contamination by synthetic fallout traced with trivalent La^{140}; other data came from contamination by acidic $La^{140}Cl_3$ solution used in preparing the synthetic fallouts. Lanthanum-140 is a beta- and gamma-emitting radioisotope with a 40-hour half-life.

The two types of synthetic fallout used were a dry mixture and a slurry. The bulk carrier materials for these synthetic fallouts were specially processed local soils. The La^{140} tracer concentrations for these synthetic fallouts were 7.5 $\mu c/g$ and 0.75 $\mu c/g$, giving a total of four combinations.[5] Previous experiments had indicated that the La^{140} was firmly adsorbed to the synthetic fallout and that cleaning operations did not desorb the La^{140} from the bulk carrier material; in other words, the detection of La^{140} radiations was a good indication of the presence of synthetic fallout.[6]

The third contaminant type was the acid La^{140} solution. The La^{140} in this solution was in a chemical form suitable for adsorbing onto most solids. The La^{140} in this form was not a tracer for a bulk carrier material; it was the contaminant.

PROTECTION

Routine rad-safe procedures were established to protect the hands of personnel working in contaminated areas: those who prepared the La^{140} solution wore surgeon's gloves, while those who performed heavier manual work wore cotton work gloves. Additional experimental protection was provided to randomly selected personnel by the application of a barrier cream prior to working in the contaminated areas.

The creams tested were Cream A, a hard, waxlike cream,[7] and Cream B, a soft, easily smoothed cream similar to common cleansing cream (Kerodex 71®). Both were proprietary preparations selected as suitable for wet work.

TABLE I

Cleaning Formulations and Procedures

Wash	Formulation	% Wt	Approximate amount per application	Cleaning sequence[d]
Soap and water	Stearate soap, G51-S-1870		Not limited	Wet hands, lather, rinse, wipe dry
Waterless hand cleaner	Ammoniacal petroleum-based proprietary formulation		15 cc	Rub into skin, wipe clean with 2 towels
EDTA	4Na-EDTA[a]	3.0	50 ml	Rub during application, rinse, wipe dry
	Disinfectant[b]	0.1		
	Wetting agent[c]	0.4		
	Water	96.5		
	HCl (to adjust pH to 7)			
Saline	NaCl (isotonic)	0.9	50 ml	Rub during application, rinse, wipe dry
	Disinfectant[b]	0.1		
	Wetting agent[c]	0.4		
	Water	98.6		
	HCl (to adjust pH to 2)			
Citric acid	Citric acid	3	50 ml	Rub during application, rinse, wipe dry
	Water	97		

[a] Tetra sodium ethylenediamine tetraacetic acid.
[b] Di-isobutylphenoxyethoxyethyldimethylbenzylammoniumchloridemonohydrate.
[c] Alkylarylpolyetheralcohol.
[d] All rinses were with tap water, all drying was with one paper towel unless otherwise noted.

CLEANING

The hand cleaning was performed by test personnel under supervision. A vigorous one- to two-minute wash was prescribed. Drying was done with paper towels. The formulations of the different washes tested and application procedures are given in Table I.

Soap and water washing was chosen as a control. The EDTA and saline solutions were selected as a result of previous work at USNRDL.[2] The waterless cleaner was selected as a typical mechanic's hand cleaner. The citric acid was recommended by the Radiological Safety Officer. Several washings using the same method were performed when radioactivity levels permitted. In some instances of unusually high beta readings more than one cleaning method was prescribed.

INSTRUMENTATION

The instrument for routine initial radiological safety monitoring was a Geiger-Muller end-window count rate meter (Beckman Model 2750). The instrument used in this study for assessing contamination on the palms of the hands was the

USNRDL Large Area Beta Detector. This instrument, designed and built by the Nucleonics Division of USNRDL, consists of a modified AN/UDR-9 radiac set, a pre-amplifier, and a detector. A 5-minute timer (Microflex timer, Eagle Signal Corporation, Moline, Illinois) replaces the normal switching and timing circuits of the AN/UDR-9 to simplify the operation of the instrument. The pre-amplifier is a 3-tube device with a voltage gain of approximately 1,000. The detector uses an 8 × 10 × ⅛-inch sheet of plastic scintillant (Scintilon B, National Radiac, Newark, N. J.). The scintillant is coupled with 10^6 centistoke DC-200 silicone oil to a segmented plexiglas light-pipe, which is coupled to a 5-inch diameter photomultiplier tube (Type 6364, A. B. Dumont Inc., Clifton, N. J.). The detector pre-amplifier combination is contained in a light-tight box with a removable cover. The instrument was set to give a 15-sec count. The physical relationship between a person with his hands in position for counting and the elements of the beta counter preamplifier is shown in Figure 1.

Two 12-μc samples of synthetic fallout were prepared for instrument standardization. Sample 1 was 0.75 μc/g San Francisco Bay mud (dried). Sample 2 was 7.5 μc/g San Francisco Bay mud (dried). The averaged 15-sec count was used as the standardization factor to convert from counts per 15 sec (c/15 sec) to microcuries (μc).

Results and Discussion

The effectiveness of the various methods tested is expressed as a residual fraction: the beta radiation reading of the palms of the hands taken immediately after a washing was divided by the beta reading taken immediately before the washing. All types of contaminant are included in the evaluation of a cleaning method unless otherwise noted.

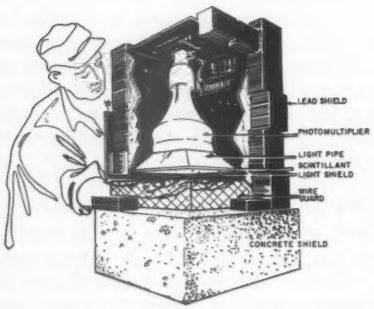

FIGURE 1. Large-area beta detector in use.

PROTECTION METHODS

The two barrier creams tested, when used in conjunction with a soap and water wash, gave approximately the same results as a soap and water wash without the protection of barrier creams (Table II).

CLEANING METHODS

The residual fractions for the soap, EDTA, and waterless cleaning methods were divided into three groups to determine gross effects due to initial contamination level. These group divisions were based on initial level: less than 0.03 μc, 0.03 to 0.3 μc, and greater than 0.3 μc. The logarithmic mean residual fractions are presented in Table II. They were normalized to 1 μc, 0.1 μc and 0.01 μc for convenience of comparison (Figures 2 and 3). The results presented are for all three contaminant types combined. The British maximum permissible level[8] of fixed radioactivity on the skin is 10^{-5} μc/cm^2, which is equal to 0.004 μc uniformly distributed on the palms of both hands. (The U. S. has no comparable maximum permissible level.)

Waterless Hand Cleaner. The averages of the first washings with waterless cleaner showed approximately the same effectiveness as the equivalent soap washings (Table II, Figure 2). A review of the washing procedure will show that while the soap and water washing method was not limited by the amount of water that could be used, the waterless method used only 15 cc of cleaner for one washing. This cleaner may be of interest from a logistics and stockpiling standpoint.

EDTA. The average residual contamination from washing with EDTA was considerably lower than that of soap and water (Table II, Figure 3). To further test the effectiveness of EDTA, we deviated from the original plan of using a single washing method; the initial washing was with soap, the second with EDTA. The result of this test showed that the residual fraction for the EDTA wash was smaller than residual fraction for the soap wash. Also, two EDTA washings removed more contamination than the one soap wash plus one EDTA wash.

Saline Solution, pH-2. The average residual contamination from washing with the acidic saline solution was considerably lower than that of soap and somewhat higher than that of the EDTA (Table II, Figure 3).

A test, similar to the special test for EDTA, was performed using the saline solution (Table II, Figure 3). The first two washings were with soap. The third was with saline solution. The residual fraction from the saline solution washing averaged about half the residual fraction for the

TABLE II
Residual Fractions From the Various Cleaning and Protective Agents[a]

Agent	Initial level range (μc)	Residual fraction and standard deviation for each wash								
		First wash			Second wash			Third wash		
		2nd count / 1st count	Std. Dev. (%)	No. of Subjects	3rd count / 2nd count	Std. Dev. (%)	No. of Subjects	4th count / 3rd count	Std. Dev. (%)	No. of Subjects
Protective										
Cream A, Soap wash	5.2 to 0.53	0.17		3	0.32		3	0.71		2
Cream B, Soap wash	2.4 to 0.01	0.40	55	10	0.74	32	9	0.91		3
Cleaning										
Soap	>0.3	0.15	282	12	0.64	52	9	0.69		4
	0.03 to 0.3	0.39	161	30	0.80	23	19	0.63	69	7
	<0.03	0.35	92	16	0.79	23	7	0.19		1
Waterless	>0.3	0.35	45	7	0.68	23	7	0.62		4
	0.03 to 0.3	0.41	41	10	0.72	18	10	0.47		2
	<0.03	0.35	74	12	0.56		2			
EDTA	>0.3	0.053	220	10	0.51	120	7	0.56		4
	0.03 to 0.3	0.06	240	24	0.59		4			
	<0.03	0.15	350	7						
Saline, pH2	2.4 to 0.01	0.12	146	23	0.55	29	10			
Citric Acid	1.0 to 0.01	0.074	298	13	0.49	38	6			
Soap EDTA	4.0 to 0.15	0.37	59	6	0.28	26	6			
Soap Saline	0.5 to 0.08	0.45	23	5	0.89	7	5	0.28	70	5

[a] Computed as logarithmic means.

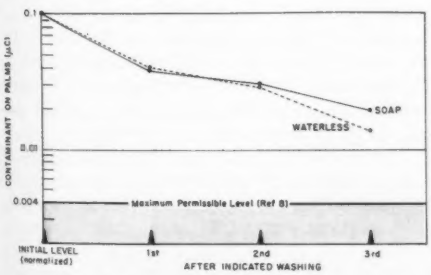

FIGURE 2. Comparison of waterless cleaner with soap and water.

equivalent soap wash, showing that the saline solution removed the contaminant to a greater degree than soap.

Citric Acid Solution. The citric acid solution was given a cursory test (Table II, Figure 3). The average residual from the citric acid wash-

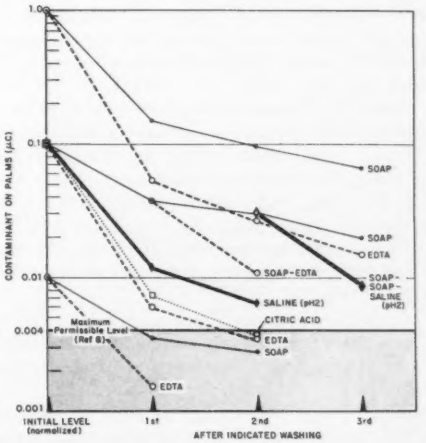

FIGURE 3. Comparison of aqueous cleaning methods.

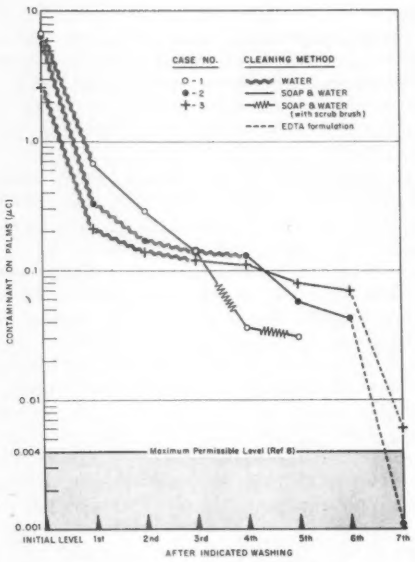

FIGURE 4. Three case studies.

ing was approximately the same as that of the EDTA and saline solutions.

Miscellaneous Cleaning Methods. Three individual case studies are reported (Figure 4). In these, an assortment of methods was used on each subject to remove a relatively high level of contamination from the hands. Conventional methods were used at the beginning and as they appeared to lose effectiveness experimental methods were tried in an attempt to reduce contamination of the hands as much as possible. In two of these cases it appeared as though contamination were fixed at approximately 0.1 μc but upon changing to EDTA wash the hands were cleaned to less than 0.01 μc.

Near the conclusion of the test series, two individuals' hands became contaminated to approximately 5 μc, presumably from the acid La^{140} solution. One sequence of soap scrub, water rinse, EDTA scrub, water rinse (using a nylon scrub brush and warm solutions, including rinse) was used as a washing procedure. The final levels were approximately 0.05 μc, or overall residual fraction of 0.01.

In another instance a man mistakenly used the waste water from the day's hand decontamination work (containing a combination of all cleaning solutions) as the wash for his hands. His hands had an initial contamination level of .006 μc, which was considerably lower than the average for the day; but the waste solution cleaned his hands to .002 μc, nearly background. This one case indicates that in the event of water shortage, cleaning solutions can, perhaps, be reused. Naturally, more data would be required to substantiate the idea and to explore possible adverse side effects.

A nylon brush was used to a very limited degree against resistant contaminant. No adverse effects were observed. The results of one case where a nylon brush was used are presented (Figure 4). Further investigation could be applied to re-evaluating the effect of scrubbing the skin with a nylon brush, perhaps after an initial wash without brushing.

SYNTHETIC FALLOUT

The synthetic fallouts used in this experiment had the best estimate of properties of fallout from a surface nuclear detonation near the test area.[5, 9] An analysis of the synthetic fallouts is reported elsewhere.[9] Although the radiation characteristics are fairly well known, no general set of physical and chemical properties for fallout can be given at present. These properties depend strongly upon the soil from the detonation site which is drawn into the radioactive cloud and mixed with the fission products. A comparison of other fallouts with the soil of the detonation sites has been used as a basis for formulating the synthetic fallouts.

MISCELLANEOUS OBSERVATIONS

Physiological Effects. No attempt was made to determine toxic effects of the cleaning preparation or barrier creams. Each person used several materials over the period of the field operation; therefore effects could not be isolated. Several persons, who did not regularly use the soft cream emollient which was available, complained of chapped skin. Previous work[3] indicated a slight toxicity of two cleaning solutions traceable primarily to the disinfectant.

Comparison of Contaminant Types. In a parallel analysis the data for soap washing were separated by contaminant type and compared, *i.e.*, acid La^{140} solution, slurry 0.75 μc/g, slurry 7.5 μc/g, loam 0.75 μc/g, and loam 7.5 μc/g. Slurry contaminant with 7.5 μc/g was the only one that showed a noticeably different residual fraction; it was apparently easier to remove than other contaminants. As there were only four data points showing this effect no definite conclusions can be drawn concerning the effect of contaminant type.

Initial Level Effect. The effectiveness of the first washing was related to the initial contamination

level. In general, a lower residual fraction was obtained from the washing of hands contaminated to a higher initial level of La^{140}. This would be expected if there were a maximum level of tightly adhering synthetic fallout. There was no observable difference in the residual fractions, with respect to contamination level, for the second or third washings.

Comparison With Previous Laboratory Study. Comparison of some of the findings from this field test and a laboratory experiment performed in 1949,[2] upon which a portion of the field test work was based, shows that in both cases EDTA and saline solutions were more effective decontamination agents than soap, leaving a residual fraction of approximately half that of soap. Laboratory experiments using rats gave much lower residual fractions than those observed at the field test; however, the second washings at the field test gave residual fractions numerically almost the same as the second washing on the skin from a cadaver in laboratory tests. An additional factor, which lends further interest to the correspondence of the findings, is that the contaminating agents were quite different: synthetic fallout (and La^{+++} in acid solution, in a few instances) was used for field work, while a neutral solution of Sr^{++} was used in the laboratory experiments.

Laboratory-scale decontamination tests were performed with the co-operation of volunteer subjects[10] at approximately the same time as the field tests. A synthetic fallout, composed of Ambrose clay-loam traced with La^{140}, was dry-sprayed onto a 10-cm^2 area of the underside of the forearm, then rubbed into the skin with a rounded glass rod.

The residual fractions resulting from the cleaning operations were much lower for the laboratory tests than for the field tests, indicating that the methods were more effective in removing the synthetic fallout under the laboratory conditions. This may have been a result of a combination of effects, among which are the type of skin studied (*i.e.*, underside of forearm vs palms), the total area contaminated, the mechanical action grinding the synthetic fallout into skin and mechanical action of scrubbing, the degree of supervision, the synthetic fallout contact time, etc.

However, the qualitative findings of both tests were essentially the same: barrier creams offered no large decontamination advantage, the first wash was the most effective wash (when a single cleaning agent was used), waterless mechanic's hand cleaner was at least as effective a decontamination agent as soap and water, and EDTA and citric acid were more effective than soap as decontamination agents.

Potential Decontamination Methods. Some cleaning formulations have been suspected of increasing the absorption of radioactive $SrCl_2$ solution into the body.[3] However, before any cleaner is disqualified for this reason, all its properties should be weighed in the light of anticipated field conditions. It may be that after the contaminant has been in contact with skin for several hours, the additional absorption caused by the use of a special cleaner would be negligible. Furthermore, it may be possible that for some instances of high level contamination, a two-part wash (such as is described in the second paragraph under Miscellaneous Cleaning Methods) would be desirable in an effort to maximize removal and minimize absorption.

The wetting agent, used alone in 0.5 per cent solution has been shown to be a good decontamination agent.[2] It may be advantageous to further evaluate this agent for absorption, toxicity, and decontamination effectiveness under field conditions.

Conclusions

The barrier cream pre-treatments did not detectably alter the effort required to remove the contaminants by soap and water washing.

The waterless hand cleaner showed the same effectiveness as soap and water in removing contaminants from the hands, and required the least total material volume of all cleaners tested.

The EDTA, saline, and citric acid solutions (as formulated) were more effective than soap and water in removing the contaminant.

There was no observable difference in decontamination effectiveness traceable to contaminant type.

There is no method yet which has shown itself to be reliable enough in cleaning contaminated hands to be used without the necessity of a radiation check after washing, to comply with peacetime maximum permissible levels.

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AIR POLLUTION TRAINEESHIPS

THE PUBLIC HEALTH SERVICE has established a grants-in-aid program to increase the number, competence, and knowledge of professional personnel engaged in the prevention and abatement of community air pollution. The limited number of traineeships at post-doctoral, post-master's, and post-bachelor's graduate levels of study of the effects, extent, assessment, or control of air pollution will be awarded to individuals desirous of obtaining such specialized training and instruction during the 1960–61 academic year.

A trainee must have suitable academic background and be accepted for admission by an educational or training institution offering a recognized degree before applying for a grant-in-aid under this program. Due consideration will be given to the adequacy, value, and appropriateness of the courses to be taken as related to the general problem of air pollution; and the qualifications, interest, and potential contribution of individuals. Stipends for 12-month, full-time traineeships will range normally from $3,000 to $4,800 with added allowances for dependents, travel, tuition and fees, and special allowances as justified.

Applicants wishing to start training during the 1960–61 academic year should submit applications as soon as possible, however awards of grants may be made at any time as vacancies occur. For full details and application forms write to the Chief, Division of General Health Services, Bureau of State Services, Public Health Service, U.S. Department of Health, Education, and Welfare, Washington 25, D.C.

ATOMIC LAW

AT THE UNIVERSITY OF MICHIGAN Legislative Research Center, Dean E. Blyth Stason, Prof. Samuel D. Estep, and Prof. William J. Peirce have conducted an extensive search into problems arising out of the impact of the age of atomic energy and radiation as it runs head on into current legal concepts. In their 1500-page book, *Atoms and the Law*, they summarize their nine years of work in this field. Among the major changes they see are: (1) Establishment of "contingent injury funds" to pay for personal injuries resulting from radiation and other atomic hazards, when their effects are not immediately apparent; (2) Legislation to clarify the liabilities involved in various types of atomic activity, balancing the value of technological advances to society with the hazard they may involve for humans; and (3) Revision of workmen's compensation laws to cover atomic cases, including some means of apportioning costs of radiation injuries where more than one employer may be involved.

The authors recommend a model atomic energy act for adoption by states to promote the development of atomic energy and the control of radiation hazards. They suggest improvements in present injury compensation plans to meet the special problems posed by the nature of radiation injuries, particularly those due to delayed effects. The needs for proper legal concepts and processes to meet these and other new problems are discussed in relation to all levels of government.

Copies of *Atoms and the Law* may be purchased from Michigan Legal Publications, University of Michigan, Ann Arbor, Michigan for $15.00 per copy.

Radiation Dosage to Medical Personnel*†

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THE use of x-ray units, radium, and cobalt-60 for medical diagnosis and therapeutic purposes has been increasing at a rapid rate during the past two decades. Daily, more individuals are engaging in the use of some form of radiation. Accumulated data and new evaluations of the damage caused by radiation have brought about a lowering of the permissible dose to 100 mr per week. More rigid measures of protection for an ever-increasing and varied group of personnel may be facilitated by a review of some of the more logical and simple means for avoiding unnecessary irradiation.

It is important to bear in mind that the use of x-ray equipment and radioactive material is not limited only to radiologists who are versed in methods of personnel and patient protection. Laughlin[1] and others have compiled information indicating that a ratio of 50 to 1 exists between the nonradiologist and radiologist; in other words, there are 50 units in operation by dentists, urologists, orthopedic surgeons, and general practitioners for each unit operated by a radiologist. One must also consider the nurses and other personnel involved in the preparation and application of radium and cobalt-60.

Consequently, when one considers radiation dosage to medical and dental personnel all of the various branches of medicine must be taken into consideration. Since the information regarding dosage is far from complete for work with all types of radiation, this paper has been limited to several specialty groups in which the factors are better known. When assembling and presenting data of this kind it must be emphasized that the results are, in each case, for a given set of conditions; a change of one factor may well produce a different result.

Dentists

The dental profession has experienced some obvious injuries from radiation. Many dentists have held the dental film in place while making an x-ray exposure. After repeated radiation exposures to the index finger and thumb, areas of dermatitis develop. Whether or not the finger or thumb is permanently damaged will depend upon the severity of the injury. It is quite probable that many dentists have already received an accumulated dose in excess of the presently accepted limits, but due to the inadequate information one can only postulate these doses.

A tabulation of film badges worn by dentists and technicians for one year[2] indicates that 82% of the people received less than the present permissible dose, whereas 18% receive more than 100 mr per week.

A survey of 20 dental offices was conducted by Spear[3] and presented a good cross section of the workload. During a 40-hour work week an average of 322 films were taken. The total time the x-ray machine was on for this number of films was found to be 0.4 hr. The average factors used for the taking of each film were 65 Kv 10 ma with 1 mm Al added filtration. The distance from the x-ray tube target to the end of the defining cone was either 7.5 or 15 inches; and in general the target to skin distance was 8 or 16 inches.

Using the above x-ray factors and a target to skin distance of 15 inches, the intensity of the beam measured in air was 17 roentgens per minute. When the 1 mm Al filter was removed the intensity increased to 30 roentgens per minute. Thus, the filter reduced the intensity 56% without degrading the quality of the radiograph. This reduction of intensity is beneficial not only from the patient standpoint, but will greatly reduce the scattered radiation striking the dental personnel.

The weekly exposure of the technician will average 118 mr at a distance of three feet from the patient, using a 15 inch FSD (focal skin distance) with 1 mm Al filter in the beam. It must be realized that this amount of radiation to the technician applies for a given set of conditions; a change in the conditions or model of units may give different results.

The scattered radiation is but a part of the dose received by the technician; there is some leakage radiation passing through the x-ray tube enclosure. Studies made by Wellock[4] indicate that the intensity of leakage radiation is from 20

* This work was done under U. S. Atomic Energy Commission Contract At(30-1)-901 with the New England Deaconess Hospital.

† This paper was presented at the April 1958 meeting of the American Industrial Hygiene Association.

mr per hour to 270 mr per hour when measured at three feet from the enclosure.

The National Committee on Radiation Protection has published in *Handbook #60*[5] recommendations for dental equipment. In part, they suggest that the tube housing shall be of a diagnostic type, the beam shall be collimated, the total filter shall be not less than 1.5 mm Al, and the operator shall stand at least five feet from the patient and well away from the useful beam.

Urologist

The urologist uses radiographic x-ray units for detailed studies of the urinary tract. Several investigators (Spalding,[6] Clayton,[7] Ritvo[8]) have carried out studies covering the amount of radiation received by these specialists when executing a retrograde pyelogram or a cystogram examination. In general, all the results fall in the same pattern.

The radiographic technique for these studies is rather elastic with the following factors: the voltage was 62 to 74 Kv, the current 200 ma, and the TFD (target film distance) 32 to 40 inches. Using these factors for the taking of two films, the hands of the physician, being close to the patient and adjacent to the main beam, would receive an average of 27 mr. This dose can be reduced one third if he were to withdraw his hands farther from the main beam. A further reduction in scattered radiation can be accomplished by the addition of a cone or diaphragm attachment to the tube head for limiting the main beam size to the size of the cassette being used. In fact, on some x-ray units this reduction would be approximately 50%. The use of added filtration in the tube head would not only decrease the scattered radiation, but would greatly reduce the patient dose; on some units the addition of 1 mm Al will decrease the patient dose by 30%.

The NCRP has suggested that all radiographic equipment shall have a total filtration equal to at least 2.5 mm Al. It further states that diaphragms or cones shall be used for collimating the useful beam.

Among other medical specialists who use x-rays in treating patients are the neurologist and thoracic and orthopedic surgeon. Of these the orthopedic surgeon is more apt to place his hands in the fluoroscopic beam as he may do during hip nailing or reduction of a fracture.

In general the use of the fluoroscope is controlled by the attending radiologist. If by chance he is not present, the surgeon may place his hands adjacent to the primary beam; his hands thus may be radiated to a dose varying from 30 mr to 500 mr. The reason for such a span of dose is dependent on whether or not there is sufficient aluminum filtration in the beam, the distance of the fluoroscopic tube from table top, and the type of fluoroscopic screen used. The NCRP has suggested that the total filter shall not be less than 2.5 mm Al and that the table top dose shall not be greater than 10 r per minute.

The scattered radiation from the patient and from the film holder slot (Bucky slot) will be covered in another section.

Radiologist

The radiation dose received by the radiologist and the trained x-ray technician has been studied by many over the past two and one-half decades. The results of these studies have not been in close agreement due to the fact that the exposure depends upon a number of variable factors.

A study of fluoroscopic units was carried out by Cowing and Spalding,[9] and others[10, 11, 12] to determine what part of the dose received by the examiner was scattered radiation from the walls. From data collected it was concluded the minimum room size should be 12 by 14 feet. This will allow at least six feet between the roentgenologist and the nearest wall. A tabulation of dose measurement covering 11 fluoroscopic rooms using tiltable fluoroscopic tables showed that with the table in the horizontal position the dose varied by a factor of 2.5. The dose when the same tables were in the vertical position varied by a factor of 3.2.

The usefulness of a lead-rubber apron for decreasing the dose received by the radiologist is demonstrated by the fact that for one of the units studied three examinations per day would have been allowable without an apron, whereas by using an apron 20 examinations could be done.

The amount of scattered radiation striking the radiologist during fluoroscopy will depend on the field size, type of table, efficiency of the lead coning, and the dose rate of the beam at the table top.

An article by Jacobson, *et al.*[13] presents a wealth of information covering the scattered radiation from many fluoroscopic units. For the present discussion the values obtained in Room #3 are of interest. The unit in this room was operated at 83 Kv 4 ma; the half-value-layer of the primary beam was found to be 3.5 mm Al. Measurements taken on the table top gave a value of 3 r per minute.

For purposes of measuring the scattered radiation, a wax phantom 7 by 8 by 10 inches was used, and the primary beam was adjusted to a

6 by 6 inch field size. The scattered radiation measurements in mr per hour were as follows:

Emerging through the lead glass of the fluoroscopic screen	0.3 mr
At the area of the patient's wrist	700 mr
Through the side panel	300 mr
At the bottom of the side panel	15–25 mr
Emerging from bucky slot (level of operator's lower trunk) and from the patient	500 mr

This last value would be reduced to 2 mr by the use of a lead-rubber shield hanging down from the end of the fluoroscopic screen carriage.

The dose received by the operator was determined by means of film badges and ionization chambers. It is of interest to note that the amount of radiation accumulated by the operator is so much less in relation to the table-top readings. Beneath the lead-rubber apron the following readings were taken: at the waist line, 6 mr per hour; left elbow, 9 mr per hour; right elbow, 10 mr per hour; and at the bottom of the apron, 4 mr per hour.

Although this discussion has been limited to the radiologist one must consider the technician and other observers. They also should be required to wear protective aprons.

Radium and Cobalt-60

The dose received by personnel handling radium or cobalt-60 applicators that are used for intracavity or interstitial therapy cannot be easily subdivided into nonradiological and radiological categories. Many nonradiological medical specialists are as proficient in administering these materials as the radiologist.

A study of personnel exposures associated with the medical use of radium and cobalt-60 was carried out by DeAmicis, *et al.*[14] covering the technique used in an active tumor hospital. Since the use of cobalt-60 is increasing, the information secured in this study will be of interest. At this institution, there are ten capsules containing 17 mc of cobalt-60 that are placed in applicators for radiating tumors of the cervix. These capsules are stored in a lead carrier having a wall thickness equivalent to two half-value layers of lead. The handles of these boxes have a source-to-hand distance of 15 cm. To carry this box from the storage vault to the preparation area requires two minutes. For this duration of exposure the worker's hand would receive a dose of 85 mr. Assuming a source-to-trunk of body distance of 30 cm, the lower trunk would receive a dose of 21 mr.

The cobalt-60 is transferred from the storage box to a lead-sterilizing box. This transfer is carried out behind a 5.7 cm thick (four half-value layer) lead-protective barrier. During this transfer the body dose would be 3 mr. Since 25 cm long instruments are used to handle the applicators, the dose to the hands would be 184 mr for the procedure time of three minutes.

It takes two minutes to transport the applicators to the sterilizer, giving a dose of 51 mr to the hand carrying the box and a body dose of 13 mr.

If we assume someone is in the sterilizing room during the 20-minute process and that he is at least 100 cm (3 feet) from the source, he or she would receive a body dose of 11.5 mr.

Following sterilization the cobalt-60 is taken to the operating room. Here the surgeon, availing himself of protection afforded by a lead shield, assembles the proper applicator and places it within the cervix. To carry out these procedures a total of 20 minutes is required. His hands would receive a total dose of 509 mr, the body dose would be 143 mr when a lead shield is between the source and his body. If no shield is used, the dose would be greater than without the use of the lead barrier.

The nursing care of these patients presented no great problem in 1954 as at that time the tolerance dose was 300 mr per week. By rotating three nurses for the patient's care, each nurse received during the treatment a dose of 168 mr. In 1957, the permissible dose was lowered to 100 mr per week, and to comply with this, the nursing schedule would need revamping.

Up to this point the figures for the amount of radiation received have been based on a specific set of conditions evaluated over a short period of time. Information regarding radiation received over such short periods of time is of little value in determining lifetime dose. Cumulative data should be kept over a period of at least one year to give any degree of accuracy to the calculation of probable lifetime dose received by a given individual or groups of specialists.

The amount of radiation received by a nurse working in the radium department for one year has been calculated from technique studies and film badges. The results are based on the following information: number of radium cases, including cancelled ones, 32; average amount of radium used per case, 53 mg; actual number of working days per year, 263; and the permissible dose for 263 days based on 16 mr per day, 4208 mr.

The film badges worn at the waist level have shown that for each case the nurse receives 80 mr. The total yearly dose would be 2560 mr or 2.56 r. This amount does not exceed the latest recommendations on accumulated permissible dose which is 15 r per year.

Film Badge Data

During February 1957, the NCRP issued an addendum to *Handbook #60* in which it was suggested that the permissible dose be lowered by one third; thus as of that date the dose became 100 mr per week.

Since we have been collecting data regarding personnel dose for several years, it was decided to review the film badge results for 1952 on this new basis and then compare them with the 1957 data.

Weekly Radiation Shown on Film Badges

Year	No. Badges	0–100 mr	100–300 mr	300+ mr
1952	10,000	91%	8%	1%
1957	12,500	96%	3%	1%

As may be seen in the table, even with the increase in number of badges worn in 1957 as compared to 1952, the percentage of badges showing little or no radiation has increased. This increase has come from the group showing moderate radiation, whereas the group receiving the most radiation remains the same. This trend of less radiation being received by medical personnel is probably the result of the many informative and educational articles that are being written in the various journals and newspapers.[15]

Summary

With the increasing awareness of radiation exposure and the advisability of utilizing techniques to reduce exposure consistent with medical and dental procedure to both workers and patients, a survey was made to evaluate exposure to those physicians and dentists employing radiation. Many medical personnel other than radiologists employ radiation such as the general practitioner, surgeon, urologist, and the dentist. It should be emphasized that among the various specialty groups varied factors of kilovoltage, current, filter, technique, etc. will result in completely different values of exposure both to the patient and worker.

In the National Bureau of Standards Handbook *X-ray Protection*, recommendations as to total filter in the diagnostic x-ray beam are made. The 2.5 mm of aluminum recommended in medical-diagnostic units greatly reduces the exposure to patients and personnel. The use of lead-rubber aprons during fluoroscopy is also recommended. This paper presents figures on protection afforded by such aprons. Other specialists can reduce their exposure considerably by keeping their hands out of the primary beam. Dentists sometimes hold film in place. By avoiding this procedure and by utilizing a total of 1.5 mm of aluminum in the beam, they can reduce exposure to themselves and to the patient.

Throughout the article exposure values are presented for different techniques employed by specialists. A summary of film badge data is presented.

It is very important with the new permissible doses of radiation as presented in the National Bureau of Standards addendum to *Handbook #60* dated February 1957 to adopt all available protective measures to reduce exposure to a minimum.

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Industrial Hygiene Features of a Petro-Chemical Benzene Plant Design and Operation

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Introduction

BENZENE is a flammable liquid and its vapors are toxic and explosive. It presents a challenge to safety and health specialists in its manufacture, storage, and handling. Low concentrations are dangerous on continued inhalation because they may cause serious blood changes. Acute high concentrations are moderately irritating to the eyes and respiratory tract. The liquid will de-fat the skin on repeated direct contact and, as a further danger, physical contact usually leads to excessive exposure through inhalation of its vapors. It has a pleasant aromatic odor in low to moderate concentrations.

Where its hazards are recognized and the equipment is designed and built to avoid these, benzene can be manufactured, stored and shipped safely. The potentially exposed person can serve as an integrating sampler where the urine sulfate-ratio technique is used to measure the degree of environmental hazard.

Industrial Hygiene Factors in Design

The project engineers obtained industrial hygiene guidance for the selection and incorporation of preventive and control features.[1] In this paper, these are described and a report is made on the degree of success attained, as measured by the first 18 months of operation. The physical and toxicological properties of benzene were kept in mind throughout the planning and design of the 30 million gallon per year plant, which has operated satisfactorily.

Four basic principles[2] served as guides in analysis of the problem and in design:

(1) Every proposed step in the series of processes was examined with respect to its capacity to release vapors.

(2) Examination of equipment with anticipated points of loss of liquid was made in light of experience with other volatile hydrocarbons in the refinery and rubber plant.

(3) For those points where liquid and vapor were to be released to the atmosphere, vapor control measures were built into the equipment.

(4) In selection of equipment, three things were considered: (a) maintenance, so as to prevent atmospheric contamination, (b) output, and (c) efficiency.

The prevailing wind is from the southeast quadrant 55% of the time, so the control house was located on the east side where it would be upwind from the manufacturing unit and products storage tankage (Figure 1). The control house is air-conditioned and the fresh air intake is located out of likely vapor drifts. No liquid pipe lines run into the control house and the adjoining laboratory. The laboratory floor space is 9 x 6 ft, which limits the likelihood that waste or extra liquid samples will be stored there. It has a high rate (100 fpm face velocity) laboratory fume hood with more than 30 fresh air changes per hour and it is separated by a solid wall from the control panel room.

All lines and vessels, manufacturing equipment and pumps are located on an open concrete pad and surfaces are sloped and paved to assure drainage into sumps. In addition to rapid surface drainage in case of spills, these surfaces permit the entire area to be flushed with water.

Lines containing benzene streams of greater strength than the original feed stock are welded instead of flanged wherever practical. Where it was necessary to use flanges at equipment, such as pumps, which must be removed for repairs, a minimum of eight bolts were used instead of the usual six, to minimize leakage.

Circulating pumps were equipped with mechanical seals to control leaks at these points. Six circulating pumps, as well as 30 control valves, have bleeder lines which discharge to the waste recovery system. These drains allow every section of the lines and all equipment that must be removed from service to be emptied of benzene prior to breaking any connection, which might allow spills and the release of vapors to the atmosphere.

Sampling cocks and flushing valves were located over a waste drain opening. Benzene and other hydrocarbons are collected in a sump where they are separated from the wash water and pumped to a closed slop tank for reclaiming. The waste sump is covered and vented through a stack 25 ft tall and 6 inches in diameter, with a slight exhaust by a steam eductor so as to disperse any

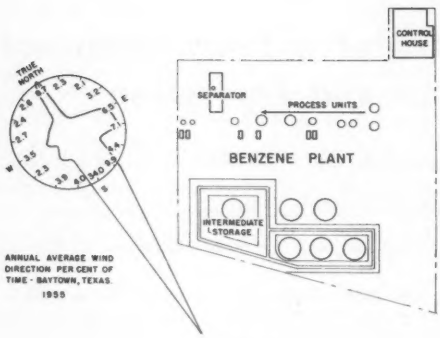

FIGURE 1.

vapor. This control item was recommended in the design stage but not installed until its need was proven through operation.

The rundown tanks have both bob gauges and electronic (automatic) gauges to measure the contents, thereby limiting the need to climb tanks and open a port. The feed storage tanks are equipped with bob gauges and are soon to be gauged electronically by a button indicator at the control house panel. These tanks have floating roofs to adjust for suction and filling changes without the loss of vapors to the atmosphere.

The truck and rail tank car loading racks are located over concrete surfaces with drains to the sewer and these slabs are sloped to allow quick flushing of spills to the waste sump.

Truck transports are filled from the bottom to reduce or minimize vapor loss. Railroad cars are filled from the top with an extension spout to deliver to the bottom of the tank, thereby minimizing splashes, mist and vapors released in tank loading operations. For all tanks, an air-operated and reset or adjustable cut-off valve is used to prevent overflow. It is only necessary to inspect the progress of the tank filling at the time the dome cap is closed.

The bottom safety cap over the discharge valve of the tank car is sealed with a neoprene gasket to prevent leaks while the car is being filled and while it is in transit.

The largest amount of benzene is loaded into barges (8000 bbl capacity) for shipment.

Preplacement Periodic Physical Examinations

Employees to be assigned to the new plant under construction were examined as soon as they were considered by operating management. As the most significant physiological change induced by continued benzene exposure is reduction in blood cells, caused by damage to the bone marrow, complete blood counts were made in addition to a special medical examination. The criteria recommended by the Medical Advisory Committee of Manufacturing Chemists' Association were found to be reasonable for selection or rejection of those to be given benzene assignments. These standards are: minimum limits of 4000 wbc; 4,000,000 rbc and 12 gm hemoglobin per 100 cc of blood.[3] Higher standards were used at Baytown.

Periodical physical examinations are given every six months to those employees regularly assigned to manufacturing, maintenance and loading operations. Although no significant exposure has been suffered to date, an adverse blood picture in the degree shown would require close exposure study and removal: 4000 wbc; 4,000,000 rbc, 12 gm hemoglobin per 100 cc, less than 100,000 platelets per mm^3, 50% polymorphonuclear white cells and more than very few immature blood cells.[3]

Training of Employees in Hygiene Aspects

Prior to start-up of the plant, the need for cooperation of employees on matters affecting safety and health was emphasized in training sessions. These classes were jointly conducted by the industrial hygienist, fire chief and safety supervisor. This training in overall hazards of benzene made the engineer's built-in controls more effective. Employees were carefully instructed in the best method to handle each piece of equipment where exposure might occur and were told fully of the hazard involved in prolonged exposures.

Although personal protective equipment had a secondary place in the program, it was supplied or located conveniently around the unit. Neoprene gloves were used for collecting samples, repairing leaking pump glands and other wet equipment. Gas masks or organic vapor respirators were used on occasion where exposure might be inherent, such as while flushing lines and inspecting tanks. Caution signs were used freely around the unit to identify the nature and degree of the hazard.

Laboratory Exposures

Blends containing various volume per cent of benzene were made with methylcyclohexane and isopentane to evaluate the potential hazard in laboratory operations.[4] These samples of 2.5, 5.0, 12.5 and 25% benzene were poured from one pint bottle to another pint bottle by means of a funnel on a laboratory bench in the corner of the laboratory having poor air circulation, so as to represent the most severe conditions. Air samples were collected at breathing level of a 6-foot man and analyzed.

A tentative method for measuring benzene in air was developed for detecting trace amounts. This method is quick and sensitive for hazard evaluation. In brief, this method consists of taking a 100 cc sample of air with an electrically heated syringe. The sample is heated to 90°C and then transferred to a 25 cc gas sampling chamber of a P-E Gas Fractometer, 75 cc of the sample being used to flush the chamber and the balance for analysis; a two-meter column employing octol as the substrate was employed at a temperature of 60°C with 15 psia of helium as the carrier gas. The area of the benzene peak was determined and from this number the ppm of benzene was obtained from a standard curve for benzene. The accuracy of this test is considered to be very good within a few ppm; however, results have not been subjected to statistical analysis.

The point of sampling was found to be very critical. For example, if the sample of air was taken about three inches nearer the pouring liquid than that previously used, the concentration increased two- to three-fold. Thus, the person 5½ feet tall would be more greatly exposed than the 6-foot person. Therefore, it was concluded that handling samples on an eight hour basis is to be conducted only under a hood if they contained 2.5% or higher benzene.

For the control laboratory procedures used in checking products' quality, the important hygiene factors were found to be:

(1) vapor pressure of benzene in liquid phase, and

(2) temperature of liquid.

Each benzene sample bottle is tagged with a colored warning card. This tag remains on the sample bottle until it reaches the washer. The mechanical washer is vented and exhausted with a minimum face velocity at the dumping trough of 100 fpm.

Hygienic Controls and Corrections

Shortly after the beginning of operations it was discovered that a leak had developed in the thermo-couple well of the clay treater. Vapors had condensed in the junction box located on top of the tower and were just about ready to spill over into a conduit leading into the control house. The advisability of sealing off all such conduits entering the control house was well illustrated by this minor incident. Another trouble spot was found at the intermediate storage tank. In the course of operation of the plant, it was found necessary to draw off about 75–150 gallons of water from the bottom of this tank three times a day. Not only was this water saturated with benzene but several gallons of benzene were invariably carried out into the open drainage ditch as a result of this draw-down technique. This undesirable situation was eliminated by piping the draw-off from the intermediate storage tank to a slop solvent tank from which benzene is recovered and recharged to the unit.

TABLE I

Room temperature	77°F–78°F				78°F–82°F			
Volume % benzene in liquid	2.5	5.0	12.5	25	2.5	5.0	12.5	25
ppm of benzene in air sample (curve values)	55	76	116	170	55	80	108	296

Air Test for Benzene

During the first ten weeks of plant operation, atmospheric sampling surveys were made in all work spaces around the benzene plant, both indoor and outdoor, at least once a week. An MSA aromatic hydrocarbon detector was used for general atmospheric testing and also as a leak detector. A Model 21 Riken Interferometer was also used on occasions. Concentrations of aromatic hydrocarbon encountered in areas generally frequented by employees did not exceed 10 ppm and were generally less than 5 ppm under most climatic conditions. In sampling the atmosphere for benzene vapor concentrations to detect leaks, spills, and wastes, readings as high as 200 ppm were observed. Although the places where these high values were reached could not be considered normal to the workers breathing zone, they were considered as both health hazards and sources of economic loss and were eliminated.

Urinary Sulfate Ratio Tests

Schrenk, *et al.*[5] developed a useful method for evaluating benzene exposure by determining the inorganic sulfate to total sulfate ratio in freshly voided urine specimens. It represents an excellent example of utilization of urinalysis for organic vapor exposure evaluation. In this test the results represent an integrated sample over the work period and reflects all routes of absorption.

The test method used is that described by Elkins.[6] Because the method is gravimetric, one needs about 25 ml urine sample for all ranges of specific gravity. The interpretation and significance of test results are based on values in Table II.

This method has two likely pitfalls for the inexperienced. First, the specimen should be collected near the end of the work shift because the generation of the organic sulfate metabolite ap-

parently begins rapidly and stops abruptly. Second, the ratio changes on aging, making it necessary to separate the sulfates shortly after the specimen is voided.

Figure 2 is a biogram of exposure to benzene in the Humble Oil and Refining Company's plant. Reading across from left to right reveals a general lessening in benzene absorption among operating personnel as a group and also reveals an exposure history for each individual since the plant was placed into operation. Scanning the results up and down affords a cross-sectional survey of plant conditions relative to benzene vapor control during the period of sampling. It should be mentioned here that follow-up of each of the six instances indicating definite exposure to benzene vapors led to discovery that the employee involved had engaged in cleaning up a benzene spill, had been lax in wearing respiratory protective equipment, or had worked a double shift. Of more than 300 tests since start-up time, only one organic sulfate ratio result has exceeded 30 per cent. In this case it was found that the employee had worked 16 hours straight through and, due to an upset in the process, had doubled his sampling frequency and tested four times as many samples as in a normal work shift. Quadrupling the opportunity for exposure obviously resulted in detectable benzene absorption; the organic sulfate portion of a urine specimen collected after 15 hours of work in this case was 31.8 per cent.

TABLE II

Significance of Urinary Sulfate Ratio

Inorganic sulfate/total	Exposure	Precautions recommended
80–95%	nil	none
70–80%	mild	vigilance
60–70%	dangerous	exposure controlled
0–60%	very dangerous	personnel removal

Summary

Those industrial hygiene factors, to carry out the principle that prevention at the design stage is most efficient and economical, are described for a benzene plant. The means and methods for minimizing benzene exposure during its manufacture, storage and loading for shipment are described.

The Medical Department examined employees before they were assigned to their jobs. Special attention was attached to any blood changes from normals. The usual standards for absence of such

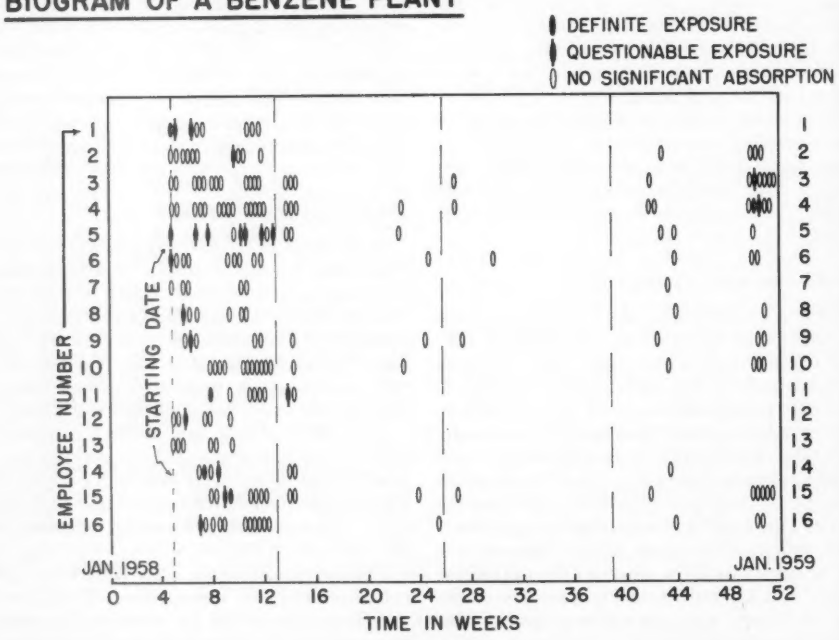

FIGURE 2.

as liver, kidney and cardiovascular diseases were applied.

Estimation of the degree of exposure and subsequent benzene absorption actually being experienced in a work environment can be obtained by means of a two dimensional sampling program. An example, drawn from actual practice in which the plant operating personnel, themselves, serve as integrating samplers for a bioassay technique, which provides both an over-all estimation of in-plant exposures and individual absorption history, is shown in Figure 2.

Acknowledgments

Mr. George Taylor made the urine sulfate-ratio tests. Mr. Albert Moskowitz was chief project engineer for the benzene plant construction. Dr. T. S. Howell, physician, directed the pre-placement and periodic medical examinations.

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Medic-Alert

INDUSTRIAL DOCTORS, NURSES AND HYGIENISTS know that persons who work with or are employed in the manufacture of certain toxic chemicals may have a sudden medical crisis away from their place of employment. In such an emergency it is vitally necessary, of course, that the attending physician should know what chemical the patient works with to determine quickly if the chemical is a critical factor in the patient's illness. In this day of increasing travel when it is possible for people to journey hundreds of miles in the matter of hours, it is a "must" for individuals working with toxic products as well as sufferers from serious allergies, diabetes, hemophilia or heart trouble to wear an identification tag engraved with information of the wearer's particlular medical problem. The Medic-Alert Foundation has devised a special stainless steel bracelet as well as disc with a Medic-Alert emblem as an answer to this problem.

The value of the Medic-Alert emblem has been recognized by doctors, hospital administrators and law enforcement officials as well as wearers throughout the United States and many parts of the world. A Medic-Alert bracelet or tag attached to the person is superior to a card or other warning statement that can be overlooked or separated from an individual in time of need.

The Medic-Alert Foundation provides a special reference file with names, serial numbers and physical data of persons who subscribe for membership and obtain an emblem. It also maintains 24-hour telephone service and accepts emergency telephone calls collect regarding members from doctors anywhere in the United States and Canada. For further information write Medic-Alert, 1030 Sierra Drive, Turlock, California.

Health Aspects of the Commercial Melting of Uranium-Contaminated Ferrous Metal Scrap

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Introduction

MANY thousands of tons of uranium-contaminated scrap steel accumulated at the Feed Materials Production Center since its inception in 1951. This paper will describe a safe method of disposing of this type of scrap. In addition, it so happened that this method proved to be quite acceptable from an economic viewpoint.

The National Lead Company of Ohio is the contract operator of the Feed Materials Production Center at Fernald, Ohio, for the Atomic Energy Commission. Here uranium ores and concentrates are received, and the uranium is extracted and processed into cast uranium metal. A detailed description of this process has been written by Arnold, Polson, and Noe[1] of the National Lead Technical Division Staff.

In the operation of such a facility, many damaged 55-gallon steel drums and much process equipment cannot be discarded because of excessive uranium contamination. A previous study was conducted in 1951 with 500 pounds of metal. This study, by Blatz, Harley, and Eisenbud[2] of the New York Operations Office of the Atomic Energy Commission, indicated that upon melting, virtually all of the uranium located itself in the slag. As a result of their study, the Atomic Energy Commission Manual Chapter 5182 was altered to provide that metal exceeding the limits of contamination and thus not directly saleable to the public could be melted and then sold.

That part of the accumulated sheet metal scrap whose contamination did not exceed that specified in Chapter 5182-05 of the Atomic Energy Commission's Manual had been sold through normal scrap channels. The remainder of the scrap, in this instance 6,000 tons, could be sold and disposed of (Chapter 5182-052) as noncontaminated scrap, provided that it was first smelted and the resulting slag was either returned to the Atomic Energy Commission or disposed of as directed by the Atomic Energy Commission. It was decided to smelt the contaminated scrap. A steel mill willing to perform this smelt was found.

The scrap not meeting the conditions for sale under Chapter 5182-05 had been stored in an open field. Prior to storing, an initial and partial decontamination removed all loose contamination, thereby reducing the health hazard potential and recovering as much uranium as was economically feasible. This scrap accumulation, being open to the weather, still presented a potential source of ground water contamination. Rain, for example, might wash any remaining uranium deposited upon it into the ground and thus into nearby streams or storm sewers.

Though this scrap was to be disposed of, the precautions necessary for guarding the health of workers performing the smelting had to be first determined, since the original report by the New York Operations Office group did not cover industrial hygiene aspects in detail. This was done by smelting a portion of the scrap under very closely observed conditions in the first or pilot stage, during which stage 45 tons was smelted. This provided the information needed for determining what industrial hygiene controls were necessary for subsequent meltings, and it also verified the findings of the New York Operations Office study pertaining to uranium contamination in the steel. It proved that the material could be melted with safety to the workers involved if mere common sense industrial hygiene controls were exercised, and that even in a large-scale operation, the uranium concentrated in the slag. It was further indicated that the most important single feature of such an operation is the provision of adequate ventilation to control the fumes or smoke emitted by the furnace.

The second stage (that is, the remainder of the 6,000 tons) was processed, taking advantage of all of the information gained during the pilot test. The second stage included a further study and evaluation of the various means of controlling the inhalation and ingestion exposures of the workers.

Methods and Data

During this operation, air samples were taken inside the plant as well as outside. These samples were taken at a sampling rate of 20 liters of air per minute through a one-inch diameter disc of Whatman No. 41 filter paper. Then the alpha

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radiation activity on these papers was counted by scintillation and proportional counters in the laboratory. Inasmuch as uranium was the only radioactive contaminant present, the alpha radiation emitted from this contaminated scrap could be directly compared with the maximum permissible concentration listed in *National Bureau of Standards Handbook 52*.

In addition to these evaluations of radioactive dust exposure, external radiation surveys were conducted on this scrap material before it was baled and also on the ingots and the slag following melting. A G-M 2610-A survey meter was used to detect beta and gamma radiation, while a Juno type meter was used to monitor the alpha radiation.

The men in areas of comparatively high airborne dust concentrations were required to wear respirators. The actual exposure of the men was monitored by air sampling, while the evaluation of their respiratory protection was done by means of urine sampling. A few drops of hydrochloric acid were added to the urine samples as a preservative and they were analyzed by the standard fluorimetric procedures in our laboratory. These samples were collected before, during, and after the entire test operation. To ensure that no contamination of the samples occurred, the samples were collected in a building separate from the steel mill prior to the workers entrance into the plant.

Figure 1 shows the approximate floor plan and size of the area involved in the melting of the uranium-contaminated scrap.

The scrap sent to this mill was stored in the designated area in the north end of the building, the slag was stored in the area south of the mold area, and the steel ingots were stored immediately outside the west side of the mill building proper. This material was always kept segregated from other uncontaminated materials at the mill until after the ingots were cast, sampled, and sold.

The arrows indicate the material flow from its entrance into the mill at the scrap storage area. This scrap was then transported by crane into the furnace. The ingots were poured in the mold area and then were stored outside on the west side of the mill. The slag which resulted was stored south of the mold area until it was shipped to Oak Ridge for disposal.

The usual locations of the men involved in this scrap melting operation are indicated on Figure 1 by black dots. Two 60-inch, 66,000-cubic-feet-per-minute capacity roof fans were installed approximately 40 feet above the furnace. By means of these fans and the manipulation of doors and windows, it was possible to bring the supply air into the building through ground-floor openings at locations affording the maximum dilution to the working area.

The arc furnace used had a removable top section containing carbon electrodes. The bottom section was charged with approximately two-ton charges of scrap bales. Each heat consisted of three or more charges. Molten metal from each heat was poured into a ladle by removing the top of the arc furnace and tilting the bottom section. The ladle, carried by an overhead crane, transported the molten metal to ingot molds into which it was poured. Flow through a hole in the bottom of the ladle was controlled by a stopper rod, and a metal test spoon was used to take samples to be tested for metal contamination from this stream, as near as possible to the start, middle, and end of the pour. The slag was retained in the ladle and was dumped into a slag thimble before solidifying.

Discussion

The numbers in black listed at each dot in Figure 2 are the average alpha air dust concentration at the areas most frequented by the men. These are to be compared with 110 alpha disinte-

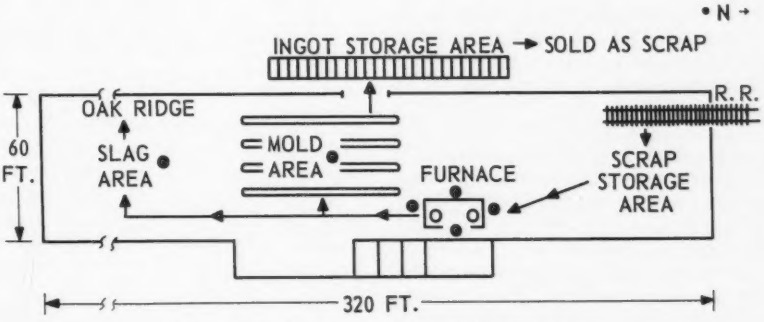

FIGURE 1. Floor plan of the steel mill area.

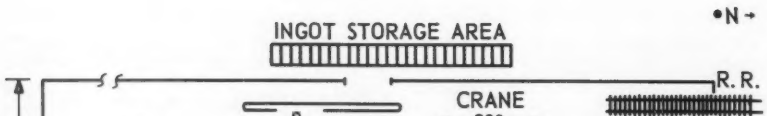

FIGURE 2. Alpha air dust concentration in the working area.

TABLE I

Summary of Air Dust Results

Sampling location	No. of samples	Concentration-α d/m/M³		
		high	low	average
Crane operation	36	526	19	228
North of furnace	44	473	1	31
South of furnace	77	412	N.D.	63
East of furnace	79	449	1	61
West of furnace	46	153	N.D.	26

grations per minute per cubic meter which, based on figures from the *National Bureau of Standards Handbook 52*, is the maximum permissible concentration for uranium. Occasionally, samples ran higher than the maximum permissible concentration figure; however, this maximum permissible concentration is based on a 40-hour work week, and therefore the averages of all sample results were used.

Table I is a summary of the air dust samples taken at the locations indicated. The range between high and low on this table is quite large, but this is not an unusual occurrence with an operation such as this. This variation is believed to be due, for the most part, to the constantly changing air currents in this large steel-mill room.

This table shows that the average concentration in the crane area was above the maximum permissible concentration. In spite of this, we believe that because of the use of respirators, the crane operators did not breathe concentrations of uranium dust or fume which were in excess of the maximum permissible concentration. The crane operators were quite cooperative in following instructions pertaining to the wearing of a tight-fitting respirator at all times.

There were seven crane operators who worked during this smelting operation. Four of these seven men never showed urine results above 0.025 milligram of uranium per liter of sample. The three others had one sample each which was slightly above that concentration. Results above the 0.025 figure never recurred on subsequent samples, but instead the uranium concentration dropped to below the 0.025 concentration. It is believed that this attests to the effectiveness and success of the respirator program at this steel mill.

Table II shows the results of urine samples for all workers before, during, and after the test. The numbers in columns A, B, C, D, and E represent the number of the workers whose uranium urinary excretion concentrations were within the ranges indicated in the first column. The ranges listed in the first column are arbitrary in that no general agreement has been reached thus far, throughout the uranium industry, as to just what concentrations indicate levels of exposure or body burdens. These samples were collected at the beginning of a shift in a building located a hundred yards from the mill. The samples were collected under supervision of a lab technician who, with the mill manager's approval, forced the men to contribute to this program by holding their pay checks until they submitted urine specimens.

Column A lists background sample results.

TABLE II

Summary of Urine Sample Results

Ranges—mg U/L	A before	B initial	C mid	D final	E 3 months after
<0.025	57	101	76	36	61
0.025 to 0.075	1	6	6	5	0
>0.075	0	1	0	3	0
Total number of samples	58	108	82	44	61
Total number of people sampled	58	58	31	44	61

These samples were collected before any uranium-contaminated scrap arrived at this mill. Column E represents samples collected approximately three months after completion of the processing of this material. The comparison between columns A and E indicates a reduction in the uranium concentration to background level when these samples were collected three months after the handling of contaminated material was discontinued. The three columns, B, C, and D, indicate the number and uranium urinary excretion concentration reached at various times during the smelting of this steel scrap. Column D, submitted on the last day of the melting operation, indicates a slight increase over previous samples. The reason for this was not possible to determine because sampling for uranium airborne concentration was not done on the last few days of this operation which preceded the urine sampling. The rise in urinary uranium concentrations indicated on column D may have resulted from unknown factors which caused an inadequacy in the ventilation system. Or, it may be that the respirators were not used as meticulously as the operation progressed. This smelting operation was originally scheduled to last for four months; however, due to mechanical difficulties at the mill, it lasted a year and, as you know, respirators are not adequate as a control measure for an extended period of time.

On the other hand, this increase in uranium urinary concentration may have been the result of dirtier working habits or some other undetected condition which arose after the midpoint of the smelting which was the time of our last air sampling for uranium.

During the course of this operation, 292 urine samples were collected. The results were interpreted to indicate an over-all low degree of exposure because the samples above 0.025 milligram per liter were of the occasional type, and subsequent samples from these same people were well below the 0.025 milligram per liter range. In the majority of instances, the samples above the 0.025 concentration range were from workers whose job was located in or around the immediate area of the furnace.

In addition to respirators, protective clothing (cotton duck coveralls, caps, and leather gloves) was furnished to the steel mill employees for this entire test operation. The clothing was an added precautionary measure because past experience has shown that is should be used.[3]

Summary of Conclusions

From the above information, it is concluded that large-scale smelting of uranium-contaminated steel can be carried out with no health hazard to the workers involved, if relatively simple industrial hygiene controls are exercised.

The air samples indicate and urine samples confirm the fact that the people doing this smelting did not receive greater than the maximum permissible air concentrations.

This study also indicates that adequate ventilation is a far more desirable means of controlling dust exposures than the use of respirators. Thus, for operations lasting for an extended duration, an efficient local exhaust system should be installed on the smelting furnace. Metal fume type respirators, if properly fitted and worn, offer adequate temporary protection but their use is highly undesirable if a permanent type operation is anticipated.

Protective clothing is recommended for such an operation as this, and it is equally important to have conveniently located sanitary facilities available for washing hands prior to eating.

Regardless of the method used for controlling the airborne contamination, it is recommended that a thorough air survey be conducted to verify that the controls are adequate if used properly. From then on, periodic spot surveys should be performed to determine whether or not satisfactory conditions are being maintained. In addition, some type of screening method, such as urine testing, is advisable as a supplementary precautionary measure.

Acknowledgments

The industrial hygiene work performed was greatly aided by the complete cooperation extended by the management of the steel mill where the scrap was smelted. Without their cooperation, the urine sampling program would have been far less successful and the general results of this study could not have been as comprehensive and conclusive.

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Some Health Hazards Associated with the Manufacture of Commercial Jet Aircraft*

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THE development and production of the 707 airplane has presented some interesting industrial hygiene problems which have required the application of engineering control measures, utilization of personal protective devices and continued medical surveillance to preclude industrial disease and injury. These problems have been related to the following manufacturing operations:

(1) Integral wing fuel tank cleaning and sealing.
(2) Hydraulic system testing and installation.
(3) Spray painting with epoxy resin paint formulations.

Each of these operations will be considered with a brief discussion on their related industrial hygiene problems.

Integral Wing Fuel Tank Cleaning and Sealing

The development of an integral or "wet" wing has presented health and safety problems in the cleaning and sealing operations necessary to make the wing fuel tight. An integral wing is defined as one in which the raw fuel is in direct contact with the structural members of the wing itself. Sealing to prevent the loss of fuel is necessary around fasteners, rivets, lockbolts, and the periphery of the entire wing structure.

In order to accomplish the seals, the metal surfaces are cleaned with methyl ethyl ketone in the confined space of the wing cavity. Subsequent to this cleaning operation a sealing material is manually applied to the desired locations. This sealer is composed of a polysulfide base material mixed with an accelerator which contains calcium dichromate and the solvent dimethyl formamide. Following this a topcoating material is brushed over the seal and the bare metal on the bottom wing panel to preclude softening of the seal and corrosion of the metal by the fuel. This topcoating material is a phenolic base with a mixture of methyl isobutyl ketone and butyl acetate as the solvent medium. It is to be remembered that these entire operations are performed manually and the estimated time spent cleaning and sealing an airplane wing (both right and left-hand sections) is about 3000 manhours. The wing cavities are small confined spaces and many of the sealing locations are such that the employees must literally sit or lie down to perform the job, as illustrated in Figure 1.

An engineering solution to the problem of wing ventilation during these operations resulted in providing exhaust systems in the sealing shops, with each system having a capacity of two air changes per minute per wing. These systems are shown in Figure 2. The ventilation has proved adequate to keep solvent vapors below threshold levels, even with several persons cleaning in a wing at one time.

For operations out of manufacturing sequence (*i.e.* out of the regular wing sealing shop) portable exhaust or blower units are utilized. Determinations of solvent vapor concentrations have generally been made with a Davis Vapotester. It is felt that the use of a properly calibrated direct-reading instrument, such as this, is more practical for day to day operating conditions than chemical determinations. This is especially true when the solvents involved are ketones or aliphatic naphtha.

Mixing of the sealants is carried out in a central shop location provided with local exhaust ventilation.

Fortunately, quality control measures demand that skin contact with the sealant be avoided. Although personal protective devices are provided, control of skin contact with the solvents such as methyl ethyl ketone, acetone, etc., is difficult, and a number of dispensary calls have been made by employees suffering from dermatitis as a result of solvent defatting of the skin. The possible fire hazards are obvious; for this reason air-driven and explosion-proof electrical equipment is used. Cleaning rags (small gauze squares) are collected in paper bags outside the wings.

Personnel cleaning and sealing are given physical examinations to screen out persons suffering from epilepsy, cardiac, lung, or skin diseases.

Hydraulic System Testing and Installation

The manufacture of multi-million dollar aircraft, which will be carrying over 100 passengers

* Presented before the Twentieth Annual Meeting of the American Industrial Hygiene Association, Chicago, Illinois, May 1, 1959.

FIGURE 1. Employee cleaning and sealing 707 wing.

FIGURE 2. Wing cleaning and sealing shop showing local exhaust ventilation.

at altitudes of 30–40 thousand feet, has necessitated the development of a fire resistant hydraulic fluid which will operate at temperatures from minus 40° to plus 200°F. This fluid, marketed by Monsanto Chemical Company, under the trade name of Skydrol 500 has presented equipment and personnel problems in its handling.

Skydrol 500 is a phosphate-ester type synthetic fluid. It contains a corrosion inhibitor, viscosity improver, and dye. Equipment-wise the fluid has a stripping effect on standard aircraft finishes and plasticizing effect on many organic materials including common rubbers. As a consequence, hydraulic system materials in contact with the fluid must be fabricated from Skydrol resistant compounds such as silicone, butyl rubber polymers, nylon, Teflon, and/or epoxy resins. Areas where leaks and spills are liable to occur must be painted with a finish which will not soften under these conditions. This paint and its application will be discussed later.

Hydraulic system components undergo routine pressure testing by mechanics working at test benches where the fluid is supplied at the desired pressure to the component. It is necessary for the mechanic to perform manual operations in attaching and disconnecting the parts from the test bench and draining hydraulic fluid back into the bench reservoir. This operation is repeated many times in an eight-hour shift.

Preliminary toxicological tests by Monsanto indicated that no serious problems would be encountered by personnel handling the fluid beyond the transient irritant effects upon the eyes and upper respiratory tract from direct contact with the fluid or its mist from a high pressure leak.

Patch testing of mechanics and Medical Section staff proved the material was not a primary irritant. No special personnel precautions were instituted beyond recommendations to avoid eye and unnecessary skin contact and to shut off any high pressure leak which might occur then to leave the area until the mist dispersed. Occasional cases of skin reactions appeared but it was felt that these were due to simple defatting of the skin as a result of prolonged or repeated contact with the fluid. Tests on various kinds of rubber and plastic gloves indicated that latex surgical or industrial gloves would last up to a week of continuous work in the fluid providing they were not punctured sooner by lock wires or sharp edges of equipment being tested. Understandably, there was some employee resentment to continuous wearing of rubber gloves. Employees were rotated in other areas for a time in an effort to minimize exposures until it was observed that more than 50 percent of the personnel were exhibiting varying degrees of skin reactions, even among employees who were most conscientious about wearing the rubber gloves. At this point patch testing was again undertaken and it showed those having the most severe skin reactions had indeed become sensitized to the fluid.

With the assistance of Monsanto an extensive patch testing program was undertaken by the Boeing Medical Section using the individual components of the hydraulic fluid in known non-sensitizing, non-irritating diluents. Fortunately the base fluid was not implicated, but the corrosion inhibitor was proved to be the sensitizing agent. Monsanto has not divulged the chemical composition of the corrosion inhibitor, however a new formulation has been developed in which this offending agent is not used.

While tests were underway by Monsanto to determine if the corrosion inhibitor could be eliminated or replaced we were able to substitute in the system component testing program another hydraulic fluid, Skydrol 7000, which does not contain the sensitizer. Mechanics installing and testing the hydraulic system with Skydrol 500 in the factory and on the flight line thereafter took precautions previously unheard of by airplane mechanics. These precautions included the use of protective creams, rubber gloves, and special emphasis on personal hygiene using a sulfonated liquid hand soap to wash off contaminated skin. A safer fluid, Skydrol 500A, has now completely replaced Skydrol 500, and these extreme precautions are no longer required.

Spray Painting with Epoxy Resin Paints

As mentioned earlier, the Skydrol hydraulic fluid has necessitated the development of a paint which will be chemically resistant to the fluid under spill and leak conditions. Such a finish was found in a paint which contains an epoxy resin formulation. Many portions of the airplane are ordinarily painted as parts in sub-assembly areas, but when specifications require that an entire airplane exterior be painted, then the industrial hygiene and safety problems become magnified.

It was realized that the resin paint formulation contained an amine hardener which would probably act as a sensitizing agent on certain individuals, and that spraying the paint would greatly increase the chances for both skin and inhalation exposures.

The painting is performed in a building where the airplanes are painted one at a time. The building has approximately six air changes per hour. The airplane is moved in under a hanging scaffold which is enclosed over the airplane fuselage. Tempered supplied air is brought in at the top of this enclosure and blown down over the

fuselage at the rate of 100 to 150 feet per minute. The overspray-laden air is discharged onto the floor and exhausted through a water-wash curtain at one side of the building. The main purpose of this tempered air is to remove quickly the overspray for quality control reasons and to provide a satisfactorily constant curing temperature. During cleaning operations prior to painting solvent vapor concentrations measured in the breathing zone are below threshold limits. When the spray painting is being performed, all employees in the building are provided with chemical cartridge respirators. Painters and their helpers are required to wear respirators, gloves, cotton hoods, goggles and coveralls. Exposed skin surfaces are covered with protective creams. Even with these precautions at least one case of sensitization has been observed among employees who have been in the area during the spraying.

Point-Source Gamma-Ray Standards

THE NATIONAL BUREAU OF STANDARDS is making available for the first time point-source standards of radioactivity. These standards are gamma-ray emitters and will be useful to research workers in approximating "ideal" conditions when calibrating scintillation counters and other beam-detecting devices.

Five of these standards are being issued under the Bureau's program to supply standards in all areas of physical sciences. The five are sodium-22, zinc-65, niobium-95, strontium-85, and mercury-203. Each standard consists of radioactive material deposited between two layers of a thin polyester tape.

The activity of each of the nuclides distributed in this form is approximately 5×10^4 gamma rays per second. Sodium-22, which has a half-life of 2.6 years, emits a gamma-ray of 1.28 Mev energy, an annihilation gamma ray of 0.511 Mev energy, and x-radiation characteristic of neon. Zinc-65, with a 45-day half-life, gives off a 1.11-Mev gamma-ray, an annihilation gamma-ray of 0.511 Mev, and x-rays characteristic of copper. Strontium-85 emits a gamma ray with an energy of 0.513 Mev and x-radiation characteristic of rubidium. Its half-life is 65 days. Niobium-95, which has a half-life of 35 days, emits a 0.768-Mev gamma ray. Mercury-203 emits a 0.279-Mev gamma-ray and x-radiation characteristic of thallium. Mercury-203 has a half-life of 46.5 days.

Further information is contained in *Standard Materials*, NBS Circular 552 (third edition), which may be obtained by writing to the Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C. (35 cents).

Tungsten for High-Temperature Coatings

High-purity tungsten can now be easily plated on metal surfaces by using a vapor deposition process which the National Bureau of Standards has developed for the Navy. The method, devised by W. E. Reid and Dr. A. Brenner of the Bureau's electrodeposition group, involves reducing gaseous tungsten hexafluoride with hydrogen by passing it over the heated object to be plated. At temperatures above 300°C, tungsten is deposited on the hot surface, and the only other reaction product, hydrogen fluoride, passes out with the excess of hydrogen.

By this method, it is possible to coat numerous simple and complex surfaces such as rocket and missile nozzles and jet engine parts. The technique also lends itself to the fabrication of tungsten articles, and may be the only way that complicated shapes of tungsten can be formed. Simple tungsten shapes for use in vacuum tubes have already been fabricated.

Tungsten is one of the few metals that possess structural strength at temperatures above 2000°C. Its extremely high melting point (3140°C), hardness, and corrosion resistance make it a desirable material for high-temperature equipment. However, until lately, the high-temperature properties of tungsten could not be effectively utilized. Its brittleness and hardness prevented it from being machined by conventional methods while its weight restricted its uses in aeronautical equipment.

News of Local Sections

Philadelphia Section

The Philadelphia Section, in keeping with their custom of past years, again participated in the Annual Fire and Safety Conference by sponsoring a number of speakers on one section of the program on March 9, 1960.

The January meeting was held at the Engineers Club and Mr. Karl Dunn, Manager of Safety and Industrial Hygiene, and Mr. George McClellan, Coordinator of Technical Information Services, of the Corning Glass Works, Corning, New York, discussed the industrial hygiene problems in glass manufacturing. The March meeting was election night. A business meeting was held after a fine dinner and a United Kingdom film on "Criticality" in radiation was shown.

St. Louis Section

The January meeting was attended by 46 members and guests. Mr. Vernon W. Meyer and Mr. G. Pat O'Connor of the Industrial Commission of Missouri explained the recent changes in the workmen's compensation legislation in the state of Missouri. With this legislation, Missouri has become the third state in theUnited States to pass a definitive law accepting industrial hearing loss as a compensable disease. A lengthy question and answer period following the formal presentation emphasized the interest and growing importance of industrial hearing loss and noise control.

New England Section

The January meeting of this Section was held at Publick House, Sturbridge, Massachusetts. Dr. Norman G. White of the Shell Chemical Corporation was the speaker of the evening. A nominating committee gave its report of nominations for the officers for the 1960–61 year.

Ohio Valley Section

Dr. Clyde M. Berry, Associate Director of the Institute of Agricultural Medicine at Iowa University spoke to the Section on the topic of occupational health in modern agriculture. The meeting was held March 11, 1960 in the auditorium of the Robert A. Taft Sanitary Engineering Center.

Personnel Notes

Lawrence B. Berger has been appointed to a new administrative post in the Bureau of Mines. This position takes him from Pittsburgh to Washington, D.C. He is now Chief, Division of Health and Accident Prevention, U.S. Bureau of Mines. Mr. Berger has been with the Bureau of Mines since 1920.

Dr. Leonard Greenburgh has resigned from his post as Commissioner of the New York City Department of Air Pollution Control to take a position as Professor and Acting Chairman of the Department of Preventive Medicine at the Albert Einstein College of Medicine, New York City. Dr. Greenburgh has been Commissioner of the Department of Air Pollution Control since the establishment of the agency in November, 1952. He is currently president of the Air Pollution Control Association.

Mr. Fred R. Ingram has become an associate of the William T. Ingram, Consulting Engineering firm. Fred will be in charge of the newly opened west coast offices of this firm, offering consultation in sanitary engineering, air pollution, water purification, sewage treatment and industrial hygiene.